Iron and Steel Engineer

Established 1907 as Proceedings of A. I. & S. E. E.

J. F. KELLY, *Editor*

CONTENTS

Volume VII. SEPTEMBER, 1930 Number IX.

Power Consumption Tests On the Timken Steel and Tube Company Blooming and Bar Mills—By F. Waldorf 442

Locomotives with Internal Combustion Engines for Steel Mill Transportation—By A. H. Candee 461

Inspection Trip—A. M. Byers Company, Ambridge, Pa. 468

Synchronous Motor Driving Hammer Mill at Central Alloy Steel Company, Improves Power Factor—By C. E. Buchan 469

Molybdenum Wound Hydrogen Furnaces for Copper Brazing—By C. M. Thompson 471

Items of Interest 478

Advertisers Index II

Editorial III

A.I.&S.E.E. National Committees for 1930-1931 IV

Published Monthly by

Association of Iron and Steel Electrical Engineers

BOARD OF DIRECTORS—1930-1931

President, F. O. Schnure, Electrical Supt., Bethlehem Steel Company, Sparrows Point, Md.

1st Vice Pres., J. J. Booth, Electrical Supt., National Tube Company, Gary, Ind.

2nd Vice Pres., J. D. Donovan, Electrical & Mechanical Supt., Republic Steel Corporation, Massillon, Ohio.

Treasurer, W. E. Miller, Electrical Supt., Bethlehem Steel Company, Johnstown, Pa.

Secretary, W. H. Burr, Electrical Supt., Lukens Steel Company, Coatesville, Pa.

Past Pres., F. W. Cramer, Chief Electrical Engineer, Republic Steel Corp., Youngstown, Ohio.

Past Pres., C. S. Proudfoot, General Manager, Vanadium Corporation of America, Niagara Falls, N. Y.

Director at Large, F. D. Egan, Electrical Superintendent, Bethlehem Steel Company, Lackawanna, N. Y.

Honorary Director, J. A. Farrington, Electrical Supt., Wheeling Steel Corporation, Steubenville, Ohio.

Director, F. W. Acker, Asst. Chief Electrician, Inland Steel Company, Indiana Harbor, Ind.

Director, N. C. Bye, Chief Engineer, Henry Disston & Sons, Inc., Tacony, Philadelphia, Pa.

Director E. C. Winfield, Chief Electrician, Coal Mines, Tenn. Coal Iron & R. R. Co., Ensley, Ala.

Director J. H. Van Campen, Chief Engineer, Republic Steel Corporation, Youngstown, Ohio.

Director, Wray Dudley, Electrical Engineer, National Tube Company, Pittsburgh, Pa.

Director, W. N. Flanagan, Special Engineer, Carnegie Steel Company, Pittsburgh, Pa.

Director, J. A. Voss,, Safety Director, Republic Steel Corporation, Youngstown, Ohio.

Honorary Director, E. Friedlaender, Pittsburgh, Pa.

Managing Director, John F. Kelly, Empire Building, Pittsburgh, Pa.

Entered as second-class matter January 25th, 1924, at Pittsburgh, Pa., under the Act of March 3rd, 1879.
Subscription Price $5.00 per Year. Single Copy $1.00.

INDEX TO ADVERTISERS

A

Alliance Machine Co. 511
Allis-Chalmers Manufacturing Co. 553
American Air Filter Co., Inc. 499
Appleton Electric Co. 530

B

Bartlett-Hayward Co. 525
Benjamin Electric Mfg. Co. 505
Blaw-Knox Company 498
E. W. Bliss Co. 550
Bull Dog Electric Products Co. 547
Bussmann Mfg. Co. 488-489

C

Century Electric Company 486
Champion Switch Company 512
Chapman-Stein Company 500-501
Clark Controller Co. 555
Cleveland Crane & Engineering Co. 523
Colt's Patent Fire Arms Mfg. Co. 496
Combustion Engineering Corporation 480
Crocker-Wheeler Electric Mfg. Co. 531
Crouse-Hinds Co. 492
Cutler-Hammer, Inc. 495-506-524-541

D

DeLaval Steam Turbine Co. 510-513
M. H. Detrick Co. 556
Doubleday-Hill Electric Co. 510

E

Economy Fuse & Mfg. Company 526
Electric Controller & Mfg. Co. 502-509
Electric Machinery Mfg. Company 545
Electrical Engineers Equipment Co. 514
Electro Dynamic Company 538
Esterline-Angus Company 494

F

Farrel-Birmingham Co., Inc. 519
Freyn Engineering Company 536

G

General Cable Corporation 522
General Devices and Fittings Co. 534
General Electric Company 483-503-Cover 4

H

Harnischfeger Corporation 527
Holophane Company, Inc. 543
Hyatt Roller Bearing Company 491

I

Iron City Electric Co. 515
ITE Circuit Breaker Co. Cover 3

J

Johns-Manville Corp. 485

K

Keystone Lubricating Company 481

L

LeCarbone Co. 516

M

Manning, Maxwell & Moore, Inc. 518
Mantle Engineering Co. 517
Martindale Electric Co. 521
Miller Company—
Ivanhoe Division 484
Moloney Electric Company 512
Morgan Construction Company 493
Morgan Engineering Company 490
Morganite Brush Co., Inc. 515

N

National Carbon Company, Inc. 507
New Departure Manufacturing Co. 487
Nichols-Lintern Co. 537
Norma-Hoffmann Bearings Corp. Cover 1

O

Ohio Electric Mfg. Co. 546
Okonite Company 529

P

Pyle-National Company 508

R

Railway and Industrial Engineering Co. 511
Reliance Electric & Engineering Co. 548-549
Rockbestos Products Corp. 539
Rollway Bearing Company, Inc. 544
Rowan Controller Co. 520

S

Shallcross Control Systems Co. 528
Shepard Niles Crane & Hoist Corp. 504
SKF Industries, Inc. 540
Stackpole Carbon Company 542
Surface Combustion Co. 552

T

Thompson Electric Co. 516
Timken Roller Bearing Co. 535
Tool Steel Gear & Pinion Co. 482
Trico Fuse Mfg. Co. 497

U

R. E. Uptegraff Mfg. Co. 514

W

Westinghouse Electric & Mfg. Co. 532-533-Cover 2
Weston Electrical Instrument Corp. 554
Edwin L. Wiegand Co. 551
Geo. D. Whitcomb Co. 479

EDITORIAL

Electricity and Industrial Safety Problems

By J. S. MURRAY*

The history of Safety can be said to parallel the history of man. During the Dark Ages of his early development the survival of the fittest and the law of self-preservation largely prevailed. However, from the best information available it would seem that as an industry, Iron and Steel can be justly credited with the first organized effort in originating the "American Plan" of safety, that is, getting the man and the management into the game and working together because they wanted to rather than because they had to.

Our Industry as we find it today presents many hazards to life which fact no doubt caused the development of accident prevention work as early as 1903 in the steel industry. Efforts were directed at that time upon the development of a special phase of plant management which quickly revealed the fact that the toll of life was not the lamentable necessity that it was believed to be previously, but that by the proper application of organized effort, purpose and money, amazing reductions in accident frequency could be effected.

One of the greatest hazards in the steel industry made its appearance about 1906. This hazard was in the application of electricity. This great world power today not only serves the steel industry, but is the greatest single force in our industrial life and human existence. It was apparent to a few far-sighted men who were responsible for the application of this great force to the steel industry in 1907 that something had to be done to educate workers in the steel industry concerning the hazards that were present if the electrification of the steel mill drives was to become a reality. This handful of men met at the Westinghouse Plant in the Fall of 1907 and laid the foundation of the Association of Iron and Steel Electrical Engineers, whose purpose it was to promote the proper application of electricity to steel mills and to provide means of safeguarding workers in every way possible. In 1910 this Association began to point the way to Industrial safety organization on a co-operative, scientific and engineering basis. At their national convention in 1911 they had a full fledged safety program that was the first of its kind in the world's history.

Rev. John McDowell was one of the speakers at this convention and it may interest you to know that the following were some of the things he said:

"The purpose to save life is the noblest of all purposes. It embodies the highest ideal of humanity. It conserves the best asset of the nation. It provides the best protection for the nation. It is the solution to one of our greatest problems, namely, the union and spirit of democracy and brotherhood."

At the national convention in Milwaukee, October 5, 1912, the Association organized what is now the great National Safety Council and a comprehensive program was developed to include Federal, States, Mines, Transportation, Manufacturers Allied Association and Iron and Steel. Thus was laid the corner stone of a National Institution whose emblem is the white cross of Universal Safety.

The organization of the National Safety Council furnishes an interesting page in the history of our national industrial development. From the original organization of 16 charter members, it has grown to more than 5,000 in membership including the largest industrial organizations in the United States and the greatest men in these organizations. It is interesting to note that in this great family that the steel industry has the lowest frequency rate of any major industry in the country. There have been numerous contributions to safety in a general way since 1833 and I believe that it would be well to mention some of them at this time.

In 1833 George Stephenson suggested the use of a steam whistle to warn people of the approach of his new locomotive.

In 1851 the first telegraphic train order was issued by Charles Minot of the Erie Railroad.

In 1868 George Westinghouse invented the air brake and was thrown out of Commodore Vanderbilt's office when he tried to sell it to the New York Central Railroad a year later.

In 1863 standard time was adopted on United States railroads.

In 1885 the first automatic coupler was used on a railroad.

In 1893 a Federal law was passed requiring **power** brakes, automatic couplers and hand holds on all railroad equipment.

Later came wireless and the great Marconi in 1894.

Later on we have the electric light and the miners' safety lamp, the products of the great Edison.

In 1903 the steel passenger car was first brought out.

Thus it will be seen that despite the absence of any organizatized safety **movement,** there were things done that saved thousands of lives yearly.

Our industrial safety problems seem on the whole fairly well in hand. Public safety today is a greater problem and our hope lies in the dynamic power and combined organized ability of such gatherings as the National Safety Congress to be held in Pittsburgh September 29th to October 3rd, 1930, and through co-ordination of every available agency applicable to the common purpose to effect a savings of 50,000 lives annually, 40% of which are children —Americans of tomorrow. I am sure that this can be done.

* Chief Electrical Engineer, Follansbee Bros., Toronto, Ohio.

Association of Iron and Steel Electrical Engineers

Board of Directors, Honorary Members and National Committees of the Association of Iron and Steel Electrical Engineers

HONORARY MEMBERS

R. H. McMASTER, President, Steel Co. of Canada, Ltd., Hamilton, Ontario, Canada.
A. C. DINKEY, President, Midvale Steel Co., Philadelphia, Pa.
E. G. Grace, President, Bethlehem Steel Corp, S. Bethlehem, Pa.
MR. W. G. CLYDE, Pittsburgh, Pa.
MR. W. H. DONNER, Buffalo, N. Y.
GANO DUNN, President, J. G. White Engr. Co., New York, N. Y.
MR. TAYLOR ALLDERDICE, Pittsburgh, Pa.
E. J. BUFFINGTON, President, Illinois Steel Co., Chicago, Ill.

BOARD OF DIRECTORS—1930-1931

PRESIDENT, F. O. SCHNURE, Electrical Supt., Bethlehem Steel Company, Sparrows Point, Md.

FIRST VICE PRESIDENT, J. J. BOOTH—Electrical Supt., National Tube Company, Gary, Ind.
SECOND VICE PRESIDENT, J. D. DONOVAN—Electrical & Mechanical Supt., Republic Steel Corp., Massillon, Ohio.
TREASURER, W. E. MILLER—Electrical Supt., Bethlehem Steel Company, Johnstown, Pa.
SECRETARY, W. H. BURR—Electrical Supt., Lukens Steel Co., Coatesville, Pa.
PAST PRESIDENT, F W. CRAMER—Chief Elect. Engr., Republic Steel Corp., Youngstown, Ohio.
PAST PRESIDENT, C S. PROUDFOOT—General Mgr., Vanadium Corp. of America, Niagara Falls, N. Y.
DIRECTOR AT LARGE, F. D. EGAN—Electrical Supt, Bethlehem Steel Co., Lackawanna, N. Y.
DIRECTOR F. W. ACKER—Asst. Chief Elect., Inland Steel Co., Indiana Harbor, Ind
DIRECTOR, N. C. BYE—Chief Engr., Henry Disston & Sons, Inc., Tacony, Philadelphia, Pa.
DIRECTOR, E. C. WINFIELD—Chief Elect., Tenn. Coal Iron & R. R. Co., Ensley, Ala.
DIRECTOR, J. H. VAN CAMPEN, Chief Engr., Republic Steel Corp., Youngstown, Ohio.
DIRECTOR, WRAY DUDLEY—Elect Engr., National Tube Co., Pittsburgh, Pa.
DIRECTOR, W. N. FLANAGAN—Special Engr., Carnegie Steel Co., Pittsburgh, Pa.
DIRECTOR, J A. VOSS—Safety Director, Republic Steel Corp., Youngstown, Ohio.
HONORARY DIRECTOR, JAMES FARRINGTON—Elect. Supt., Wheeling Steel Corp., Steubenville, Ohio.
HONORARY DIRECTOR, E. FRIEDLAENDER, Pittsburgh, Pa.

JOHN F. KELLY, Managing Director—Empire Building, Pittsburgh, Pa.

NATIONAL COMMITTEES FOR 1930-1931

STANDARDIZATION COMMITTEE

Chairman, F. D. Egan, Elec. Supt., Bethlehem Steel Co., Lackawanna, N. Y.
W. S. Hall, Supt. Engr. and Const., Illinois Steel Co., So. Chicago, Ill.
A. W. Steed, Supt. Maint., American Rolling Mills Co., Middletown, Ohio.
F. W. Cramer, Chief Elec. Engr., Republic Steel Corp., Youngstown, Ohio.
W. T. Snyder, Supt. Power & Con., National Tube Co., McKeesport, Pa.
J. E. Fries, Chief Engr., Tenn. Coal Iron & R. R. Co., Birmingham, Ala.
James Farrington, Elec. Supt., Wheeling Steel Corp., Steubenville, Ohio.
G. Rees Carroll, Elec. Supt., Jones & Laughlin Steel Corp., Aliquippa, Pa.
A. J. Standing, Elec. Supt., Bethlehem Steel Co., Bethlehem, Pa.

PAPERS COMMITTEE

Chairman, A. C. Cummins, Elec. Supt., Carnegie Steel Co., Duquesne, Pa.
W. N. Flanagan, Special Engr., Carnegie Steel Co., Pittsburgh, Pa.
J. C. Reed, Elec. Supt., Bethlehem Steel Co., Steelton, Pa.
Feodore F. Foss, Asst. to Pres., Wheeling Steel Corp., Wheeling, W. Va.
C. J. Smith, Asst. Elec. Engr., Illinois Steel Co., So. Chicago, Ill.
J. J. Booth, Elec. Supt., National Tube Co., Gary, Ind.
J. D. Donovan, Supt. Elec. & Mech. Dept., Republic Steel Corp., Massillon, Ohio.
A. L. Freret, Asst. Elec. Eng., Tenn. Coal Iron & R. R. Co., Birmingham, Ala.
W. J. Harper, Chief Engr., Republic Steel Corp., Buffalo, N. Y.
S. S. Wales, Chief Elec. Engr., Carnegie Steel Co., Pittsburgh, Pa.
W. B. Shirk, Gen. Engr., Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.
J. D. Wright, Engineer, General Electric Co., Schenectady, N. Y.
A. M. McCutcheon, Vice Pres., Reliance Elec. & Engr. Co., Cleveland, Ohio.
R. W. Davis, Engineer, Allis Chalmers Mfg. Co., Milwaukee, Wis.
B. D. Christian, Dist Mgr., Crocker Wheeler Electric Mfg. Co., Ampere, N. J.
G. R. McDermott, Vice President, Chapman Stein Co., Mt. Vernon, Ohio.
Walter de Fries, Chief Engr., William B. Pollock Co., Youngstown, Ohio.
E. Kieft, Engr., of Tests, Illinois Steel Co., Gary, Ind.
A. D. Adams, Asst. Gen. Supt., Spang Chalfant Co., Inc., Ambridge, Pa.
F. J. Binckes, Asst. Chief Engr., Inland Steel Co., Indiana Harbor, Ind.
W. H. Baltzell, Chief Engr., Canadian Steel Co., Ojibway, Can.
L. A. Wynd, Master Mechanic, Keystone Steel & Wire Co., Peoria, Ill.

EDITING COMMITTEE

Chairman, Geo. J. Walz, Asst. Elec. Engr., Bethlehem Steel Co., Steelton, Pa.
R. S. Shoemaker, Supt. Rolling Mills, American Rolling Mills Co., Middletown, Ohio.
C. L. Baker, Management's Repr., Bethlehem Steel Co., Buffalo, N. Y.
L. C. Edgar, Chief Engr., Edgar Thomson Works, Carnegie Steel Co., Braddock, Pa.
Wray Dudley, Elec. Engr., National Tube Co., Pittsburgh, Pa.
F. A. Wiley, Elec. Supt., Wisconsin Steel Works, Chicago, Ill.
F. E. Leahy, Fuel Engr., Youngstown Sheet & Tube Co., Youngstown, Ohio.
R. C. Boak, Supt., Edgewater Steel Co., Edgewater, Pa.

DEVELOPMENTS IN ROLLING MILL PRACTICES COMMITTEE

Chairman, R. S. Shoemaker, Supt. Rolling Mills, American Rolling Mills Co., Middletown, Ohio.
J. H. Van Campen, Chief Engr., Republic Steel Corp., Youngstown, Ohio.
W. H. Ramage, Pres., Valley Mould & Iron Co., Hubbard, Ohio.
L. C. Edgar, Chief Engr., Edgar Thomson Works, Carnegie Steel Co., Braddock, Pa.
C. H. Hunt Vice Pres., Mid West Steel Corp., Chicago, Ill.
G. L. Warren, Chief Engr., Sharon Steel Hoop Co., Sharon, Pa.
R. B. Gerhardt, Asst. Genl. Mgr., Bethlehem Steel Co., Steelton, Pa.
Barton R. Shover, Consl. Engr., Pittsburgh, Pa.
P. C. Haldeman, Chief Engr., Lukens Steel Co., Coatesville, Pa.

MEMBERSHIP COMMITTEE

Chairman, H. E. Davis, Elec. Supt., Interstate Iron & Steel Co., Chicago, Ill.
E. H. Wentz, Elec. Supt., National Tube Co., Lorain, Ohio.
M. E. McGrail, M. M., Great Lakes Steel Co., Ecourse, Mich.
E. C. Marshall, Elec. Supt., Youngstown Sheet & Tube Co., Indiana Harbor, Ind.
H. B. Conover, Supt. Elec. and Mech. Depts., Carnegie Steel Co., Mingo Junction, Ohio.
A. J. Whitcomb, Elec. Engr., Freyn Engineering Co., Chicago, Ill.
N. Farrar, Dist. Mgr., Harnischfeger Corp., Milwaukee, Wis.
Kenneth Raynor, Elec. Supt., Bethlehem Steel Co., Bethlehem, Pa.
Linn O. Morrow, Elec. Engr., Schaff Building, Philadelphia, Pa.
W. W. Garrett, Elec. Engr., Tenn. Coal Iron & R. R. Co., Ensley, Ala.
J. E. Wood, Sales Engr., Monitor Controller Co., 1940 East 6th St., Cleveland, Ohio.
E. A. Hurme, Engr., Clark Controller Co., Empire Bldg., Pittsburgh, Pa.
M. J. Conway, Comb. Engr., Lukens Steel Co., Coatesville, Pa.
R. R. Shepherd, Elec. & Mech. Engr., A. M. Byers Co., Ambridge, Pa.
A. R. Lintern, Secretary, Nichols Lintern Co., Cleveland, Ohio.
L. Ellman, Vice Pres., M. H. Detrick Co., Empire Bldg., Pittsburgh, Pa.
J. Leo Scanlon, Sales Engr., Ellicott Square Bldg., Buffalo, N. Y.
G. R. Thatcher, Elec. Engr., Midland Coke & Iron Corp., St. Louis, Mo.
John B. Looney, Elec. Dept., Tenn. Coal, Iron & R. R. Co., Fairfield, Ala.
H. D. Esterly, Asst. Elec. Supt., Alan-Wood Iron & Steel Co., Conshohocken, Pa.
Geo. Fish, Elec. Supt., McKeesport Tin Plate Co., McKeesport, Pa.

SPECIAL COMMITTEE ON BEARINGS

Chairman, F. D. Egan, Elec. Supt., Bethlehem Steel Co., Lackawanna, N. Y.
D. M. Petty, Supt. Service Depts., Bethlehem Steel Co., Bethlehem, Pa.
E. Lewis, Elec. Supt., Youngstown Sheet & Tube Co., Youngstown, Ohio.
J. H. Van Campen, Chief Engr., Republic Steel Corp., Youngstown, Ohio.
R. H. DeMott, SKF Industries, Inc., New York, N. Y.
J. M. Kelly, Hyatt Roller Bearing Co., Pittsburgh, Pa.
Fred Waldorf, Timken Roller Bearing Co., Pittsburgh, Pa.
D. E. Batesole, Norma Hoffmann Bearings Corp., Stamford, Conn.
H. F. Brenholts, Fafnir Bearing Co., Pittsburgh, Pa.
Samuel Farrell, Rollway Bearing Co., Pittsburgh, Pa.
L. A. Cummings, Chief Engr., Marlin Rockwell Corp., Jamestown, N. Y.
R. J. Harry, Sales Mgr., Alliance Machine Co., Alliance, Ohio.
J. D. Scully, Elec. Engr., National Tube Co., McKeesport, Pa.
H. C. Mosley, Elec. Supt., Wheeling Steel Corp., Portsmouth, Ohio.
R. L. Brown, New Departure Mfg. Co., Bristol, Conn.
C. J. Swan, Orange Roller Bearing Co., Orange, N. J.
W. C. Suppler, Elec. Supt., Tenn. Coal Iron & R. R. Co., Ensley, Ala.
C. J. Smith, Asst. E. E., Illinois Steel Co., So. Chicago, Ill.
E. C. Marshall, E. E., Youngstown Sheet & Tube Co., Indiana Harbor, Ind.
R. F. Chaffin, Supt. Power, Pittsburgh Crucible Steel Co., Midland, Pa.
Wm. Jackson, Elec. Supt., Carnegie Steel Co., Homestead, Pa.
F. H. Barnard, Sales Engr., Morgan Engineering Co., Alliance, Ohio.
Karl Runkle, Mgr. Sales, Mining & Steel Mill Section, General Electric Co., Schenectady, N. Y.
A. M. McCutcheon, Reliance Electric & Engineering Co., Cleveland, Ohio.
J. L. Brown, Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa.
J. R. Lewis, Crocker Wheeler Electric Mfg. Co., Pittsburgh, Pa.
E. A. Mudge, Electro Dynamic Co., Bayonne, N. J.
W. E. Miller, Elec. Supt., Bethlehem Steel Co., Johnstown, Pa.
G. E. Reiff, Allis Chalmers Mfg. Co., Norwood, Ohio.
R. C. Parks, Century Electric Co., Pittsburgh, Pa.
C. C. Hutchins, Elliott Co., Ridgway, Pa.
R. J. Wadd, Mech. Engr., Harnischefeger Corp., Milwaukee, Wis.
W. C. Heinle, Chief Engr., Cleveland Crane & Engineering Co., Wickliffe, Ohio.
Wray Dudley, Elec. Engr., National Tube Co., Pittsburgh, Pa.
G. Rees Carroll, Elec. Supt., Jones & Laughlin Steel Corp., Aliquippa, Pa.
Stanley Grand Girard, Chief Elec. Engr., Sharon Steel Hoop Co., Sharon, Pa.
T. J. Flaherty, Elec. Supt., American Rolling Mills Co., Ashland, Ky.
L. V. Day, Works Engr., American Steel Foundries, East St. Louis, Ill.
R. Brock, Chief Engr., Spang Chalfant Co., Inc., Etna, Pa.
J. A. Clauss, Chief Engr., Great Lakes Steel Corp., Ecourse, Mich.
W. Springfield, M. M., American Sheet & Tin Plate Co., Wellsville, Ohio.

ILLUMINATION COMMITTEE

Chairman, R. F. Sanner, Asst. Elec. Engr., Carnegie Steel Co., Duquesne, Pa.
P. C. Keller, Ivanhoe Div. of the Miller Co., Cleveland, Ohio.
S. G. Hibben, Com. Mgr., Westinghouse Lamp Co., Bloomfield, N. J.
H. J. Walter, Asst. Elec. Supt., Jones & Laughlin Steel Corp., Pittsburgh, Pa.
A. R. Lintern, Sec., Nichols Lintern Co., Cleveland, O.
C. W. Roy, Sales Engr., Wheeler Reflector Co., Pittsburgh, Pa.
A. J. Thompson, Pres., Thompson Electric Co., Cleveland, Ohio.
J. C. Ritchey, Elec. Engr., Pressed Steel Car Co., McKees Rocks, Pa.
D. W. Blakeslee, Illum. Engr., Pittsburgh, Pa.
D. H. Tuck, Engr., Holophane Co., New York, N. Y.
Carlton Ostrum, Sales Engr., Benjamin Elec. Mfg. Co., Pittsburgh, Pa.

(Please turn to Page 474)

Power Consumption Tests On The Timken Steel and Tube Company Blooming and Bar Mills *

By F. WALDORF†

While it is true that considerable publicity has been given to the progress so far made in the uses of anti-friction bearings in steel mills, very little space has been devoted to the economic successes that have resulted from the numerous applications that are now in service.

No one need longer be reminded that the functions of a roller bearing are, first, that of almost entirely eliminating frictional losses in the equipment in which it is installed; secondly, that of effectually reducing lubrication, maintenance and renewal costs to extremely low minimums; and finally, in the case of rolling mills, that of maintaining such close alignment of rolls and passes as to both improve the quality of the product rolled, and to increase the output through longer uninterrupted operation of the unit itself.

It does, however, interest everyone to know to what extent the bearing is fulfilling these requirements, and no better method can be found for imparting such knowledge than that of conducting extensive tests and publishing the results. These, if convincing, should inspire confidence in the mind of the public and create a desire on its part to use this type of bearing in its equipment.

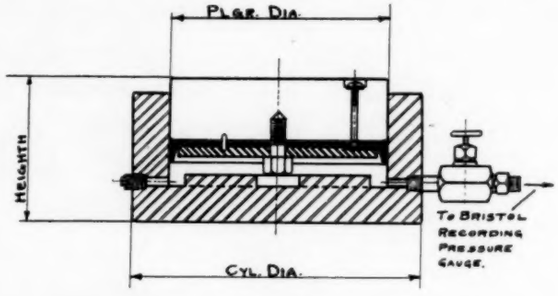
The Timken Roller Bearing Company enjoys the dual distinction of being able on the one hand, to produce the steel which enters into the manufacture of its products, and, on the other hand, to reverse the process and, to a large extent, prove them up in the very mills that originally rolled the steel.

The members present are more or less familiar with our various mills. Numerous articles have lately appeared in the trade journals describing them, and a few months ago the Association sponsored an inspection trip through our plant while it was in full operation. It, therefore, appears in order to forego a prolonged description of our rolling equipment this morning, and to confine our time to reporting the results of power tests, which, through the co-operation of the General Electric Company, have just been completed.

In planning the program for these tests, it was arranged that the General Electric Company's engineers would take all power readings, and wherever possible, the Timken engineers would direct their attention toward obtaining rolling pressures, temperatures, reductions and elongations, and any other data that might be used to derive information which could be added to the general store of knowledge that exists of the art of rolling steel.

All electrical instruments such as recording and integrating meters, tachometers, etc., were furnished by the General Electric Company. The testing cylinders, recording pressure gauges, and pyrometers were furnished by the Timken Roller Bearing Company.

Figure I shows a typical cross-section of a testing cylinder, and the table lists the sizes of the cylinders and plungers that were used. The capacities ranged from 75,000# to 1,000,000# at 12,000# per square inch hydrostatic pressure on the plungers. This is the maximum the recording pressure gauges will stand, although it was never reached at any time during our tests.



TESTING CYLINDERS

PLGR DIA.	CYL. DIA.	HEIGHTH	CAPACITY @ 12,000# □"	No. USED IN TEST
10"	13 3/4"	7"	1,000,000	1
9"	11"	6 3/4"	625,000	1
5 1/2"	7 1/4"	5 1/2"	300,000	1
5"	7"	5"	225,000	1
4 1/2"	5 3/4"	3 1/2"	150,000	2
2 3/4"	4 1/2"	4 1/2"	75,000	1

FIG. 1.

In order to eliminate the necessity of calculating the cup leather friction losses, the cylinders were all calibrated in testing machines before they were used in the mills.

Curves were drawn to show the plunger loads which corresponded to the various pressures that were recorded on the strip charts of the Bristol Recording Pressure Gauges, and these curves were later used to determine the pressures imposed on the roll neck while the steel was in a pass.

The cylinders, tubing and recording gauges were carefully filled with glycerine and water. Due care was taken to eliminate all of the air from the system by forcing the fluid through the various connections before and while the joints were screwed up. 1/16" I.D. Copper tubing was used in order to eliminate the lag in the system. Figure 1a shows a portion of a strip chart taken while rolling a 21" 5660# Ingot in the Blooming mill. The speed of the chart was 3 inches per minute. It is easy to note that the arc scribed by the needle closely paralleled the graduations on the chart and that there was practically no lag in the system.

* Paper presented at Annual Convention, A. I. & S. E. E., Buffalo, June 18, 1930.

†District Manager, Steel Mill Division, Timken Roller Bearing Co., Canton, Ohio.

4000# /□" strip charts were used in order to permit of reading the average hydrostatic pressure more accurately. The readings were all multiplied by three when the actual plunger loads were obtained from the calibration curves.

mill took readings simultaneously and later computed the lengths from them.

The temperatures were read before the steel entered a pass. This required only one operator since the cylinders registered the pressures for the top

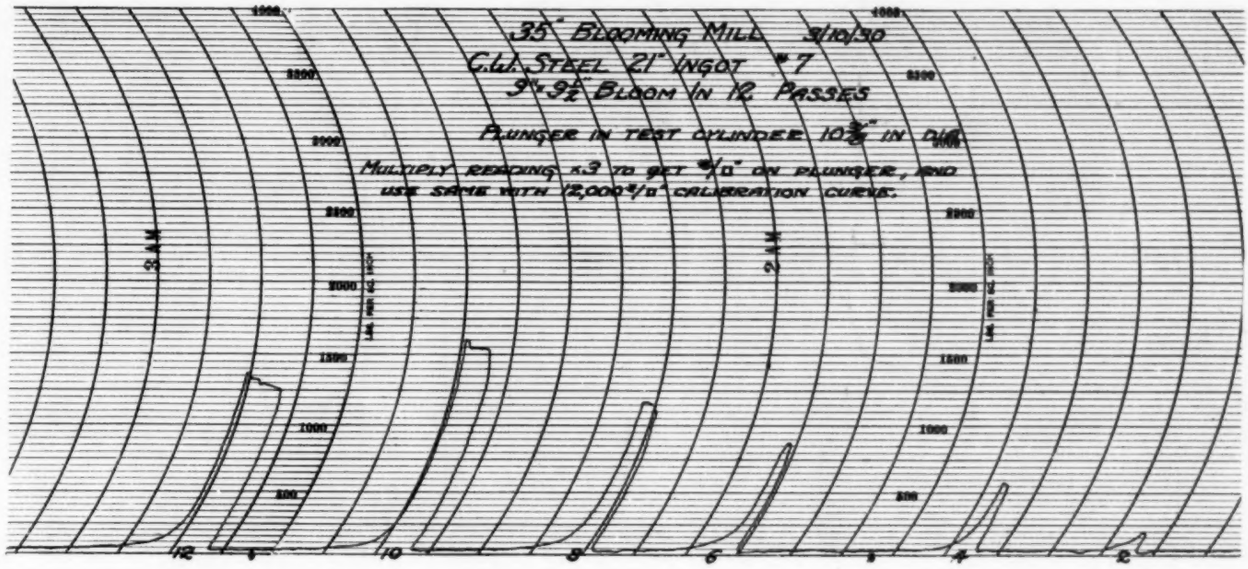


FIG. 1A.

Except for the 150,000# cylinders, only one of each capacity was available during the tests. Only the pressures imposed upon one roll neck were taken from which the total rolling pressures were calculated by the beam reaction formula. In several instances, however, two cylinders were used in combination as will be shown later.

Wherever possible, cross-sections of the stock were cut from bars as they were being rolled, or, from pieces laid aside progressively after they had gone through their respective number of passes. This, in the case of the Blooming Mill, required the laying out of twelve ingots from which sections were cut and measured for areas.

All lengths were obtained from foot, and half foot, marks which were painted on the side guards of the tables. Two operators on each side of a

passes only. There were, however, several tests during which the pressures could be taken for both top and bottom passes, and during these, two opticals were called into use.

The size of steel entered, its weight and analysis, were obtained from the recorders at the different mills.

Testing was begun on the 35" 3H. Blooming mill after which the 28" 3H., 22" 3 and 2H Bar mills, and the 18", 16" and 12" Merchant mills were taken up in the order named. The present report, however, covers only the 35", the 28", and the 22" mills because the results of the tests on the Merchant mills have not yet been analysed.

Figure 2 shows the 35" Mill and Drive. This unit, which is entirely plain bearing equipped, received 19", 21" and 22" Gathmann fluted ingots

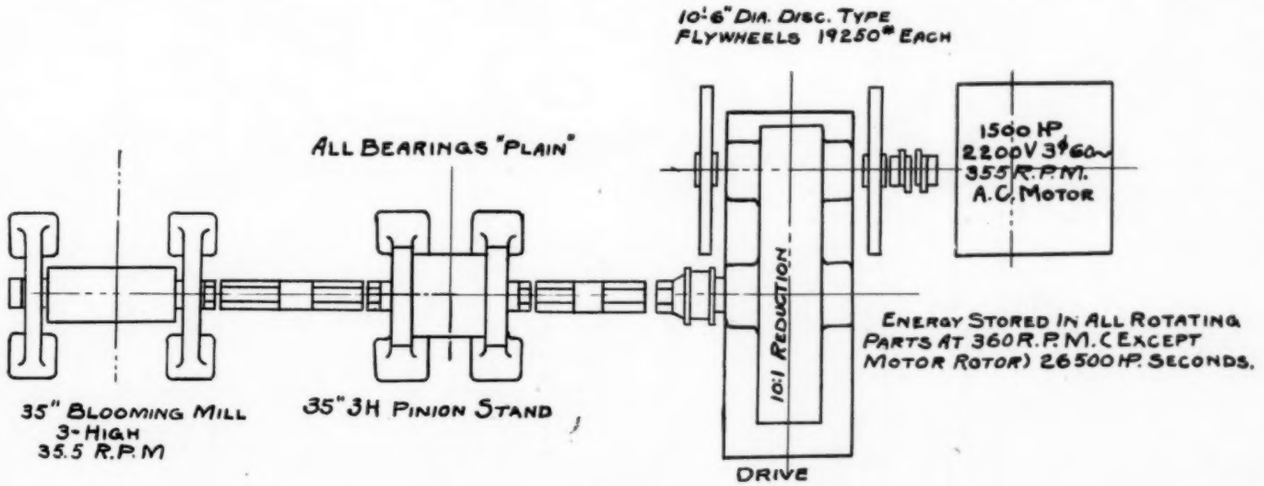


FIG. 2.

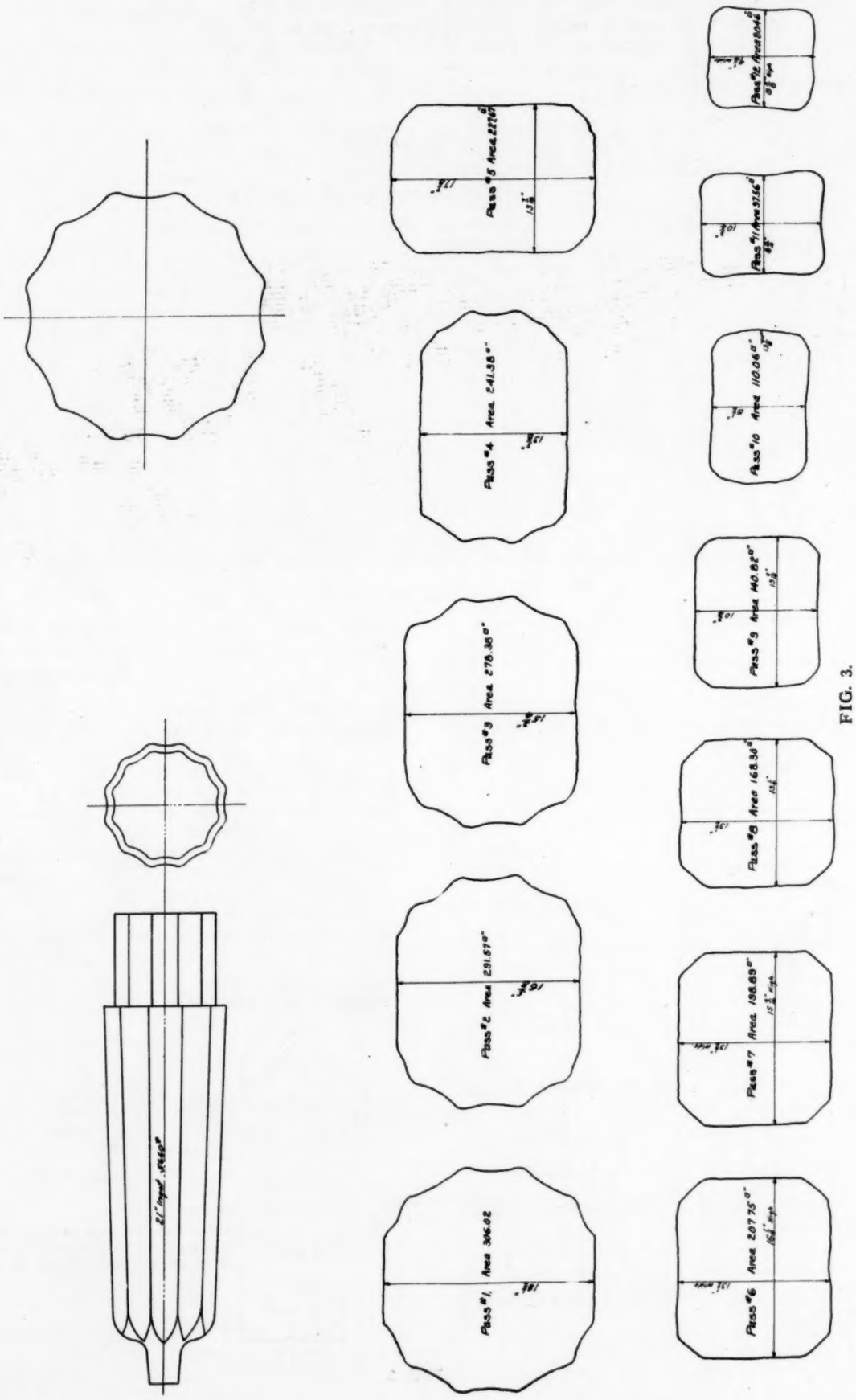
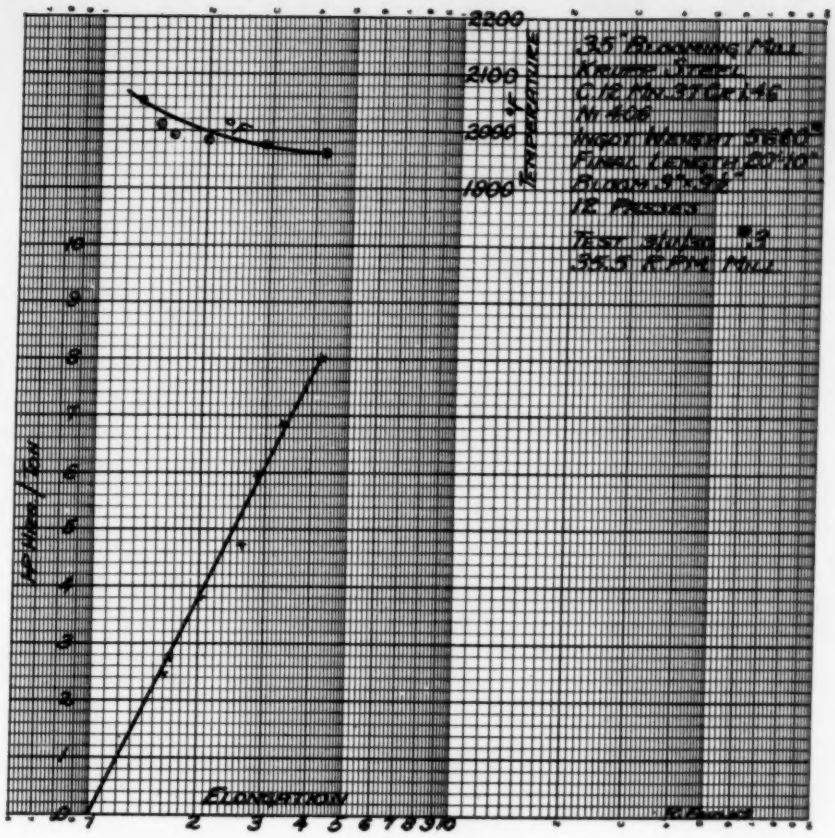
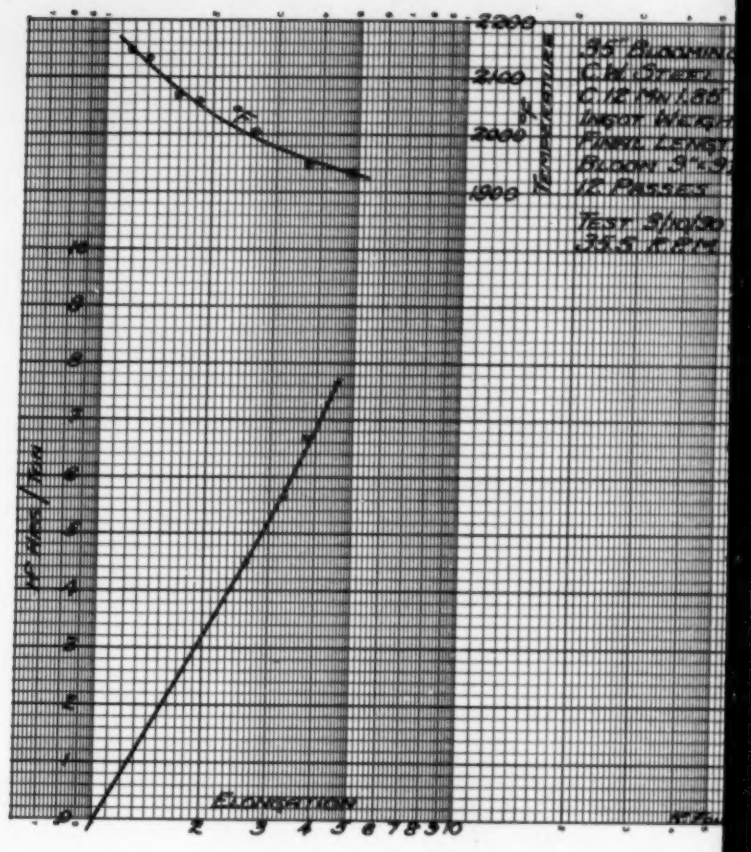

Pass #1 Area 306.02
Pass #2 Area 291.57
Pass #3 Area 278.38
Pass #4 Area 241.38
Pass #5 Area 227.60
Pass #6 Area 207.75
Pass #7 Area 198.69
Pass #8 Area 168.30
Pass #9 Area 140.82
Pass #10 Area 110.06
Pass #11 Area 97.16
Pass #12 Area 80.46

FIG. 3.

A.

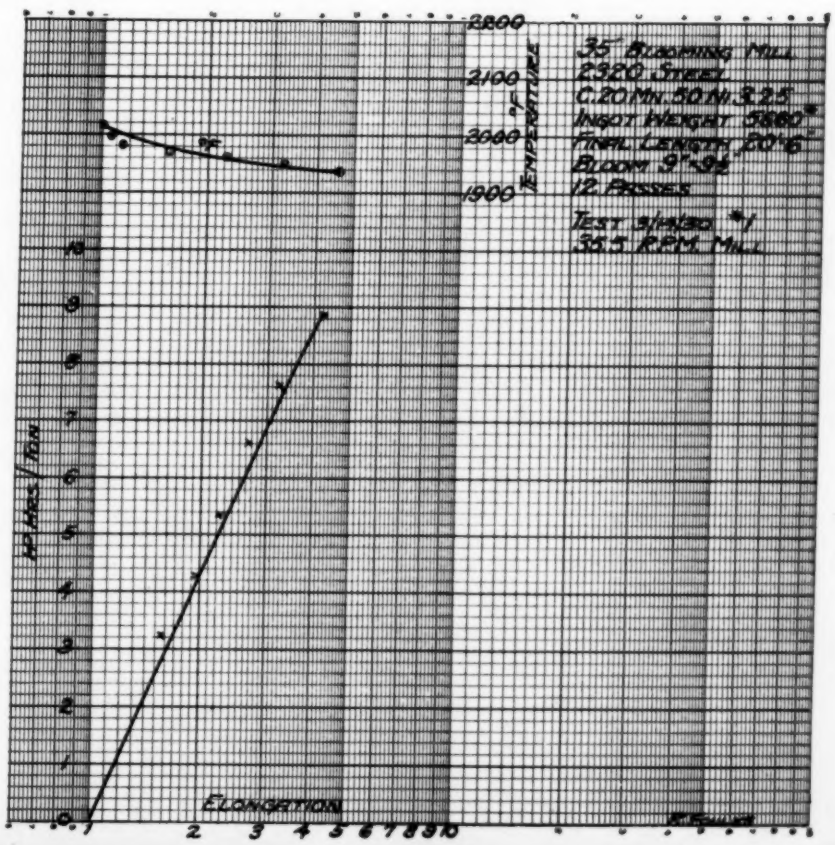


B.

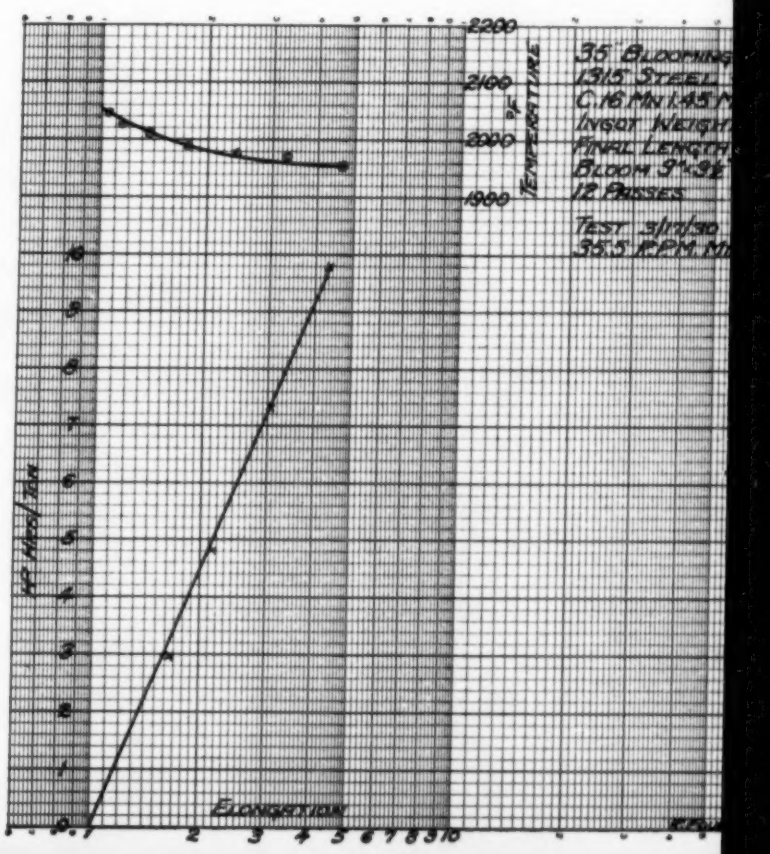


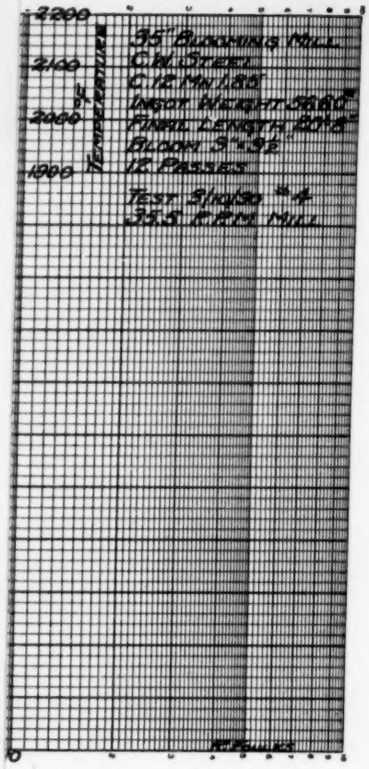
Steel	C.	Mn.	Cr.	Ni.	Mo.	Temp range	Total n	Ft Hrs/Ton Total n
Krupp	.12	.37	1.46	4.06		2045 - 1960	4.16	8.05
C.W.	.12	1.85				2060 - 1930	4.13	7.7
C.W.	.12	1.85				2060 - 1930	4.13	8.6
2320	.20	.50		3.25		2015 - 1945	4.10	8.9
1315	.16	1.45			.25	2045 - 1955	4.30	9.8
1040	.39	.68				2025 - 1965	4.43	9.5

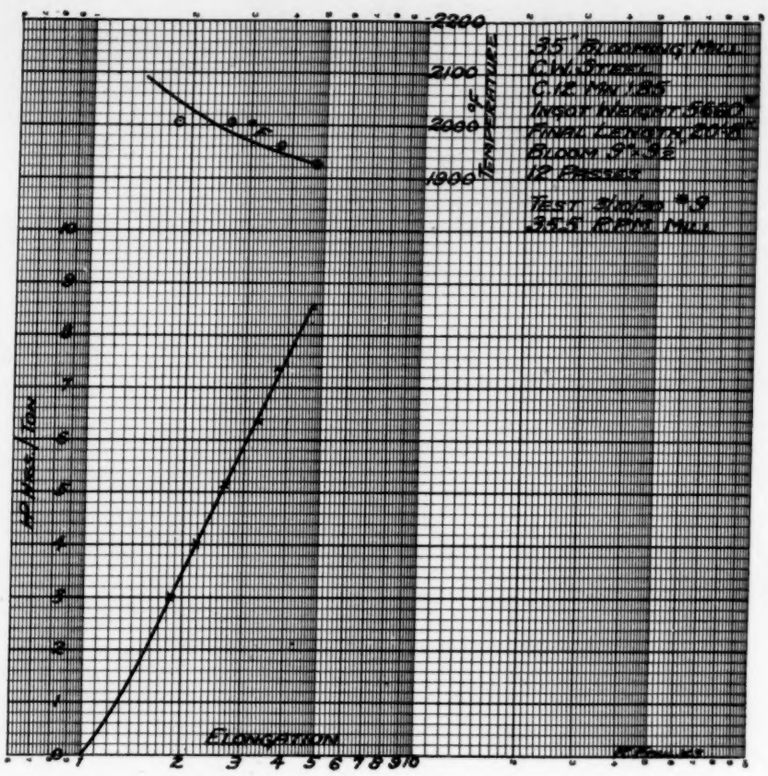
D



E

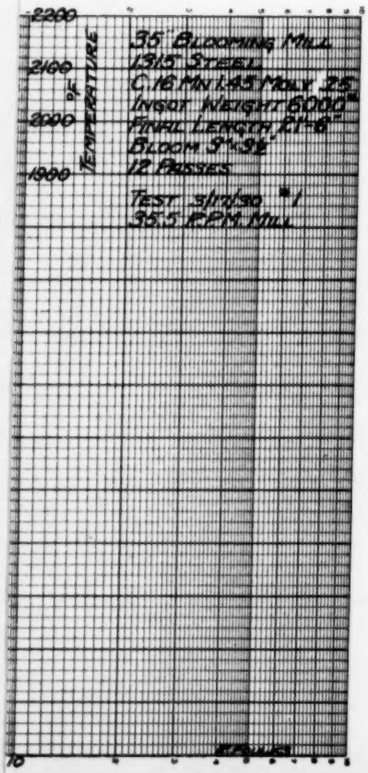


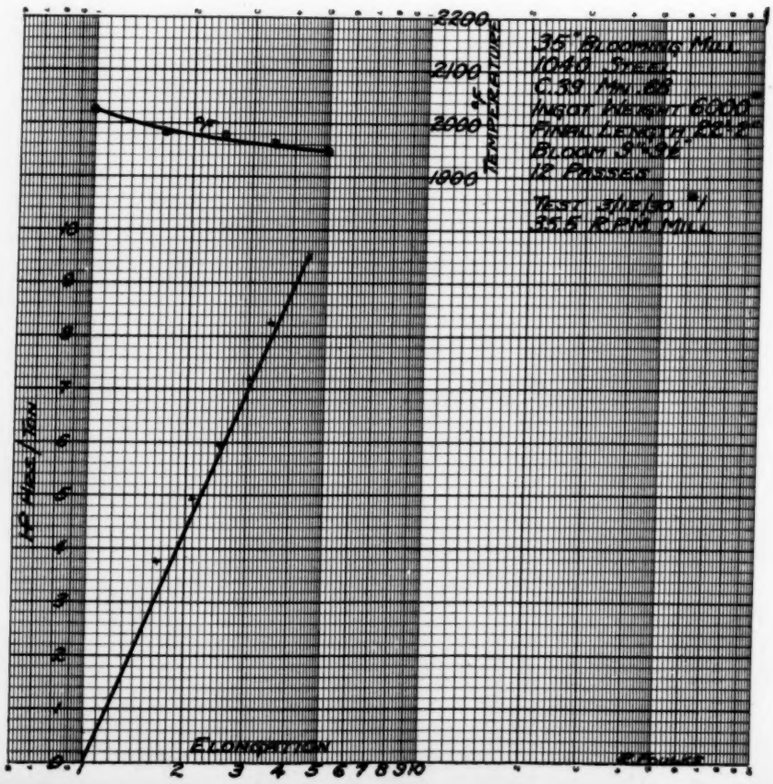




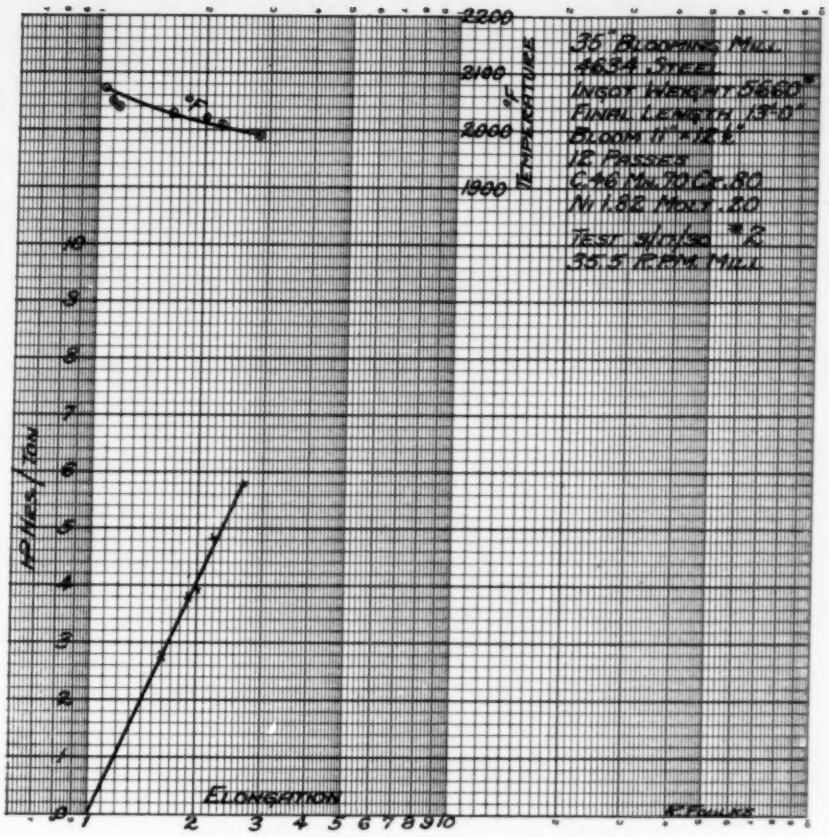
nge	Total n	HP Hrs/Ton Total n	Ingot	Product
960	4.16	8.05	21'	9"x 9½"
930	4.13	7.7	21"	"
930	4.13	8.6	21"	"
945	4.10	8.9	21"	"
955	4.30	9.8	22"	"
965	4.43	9.5	22"	"

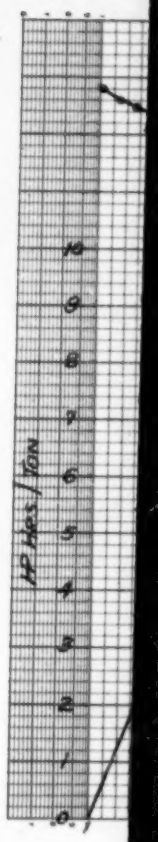
FIG. 4.



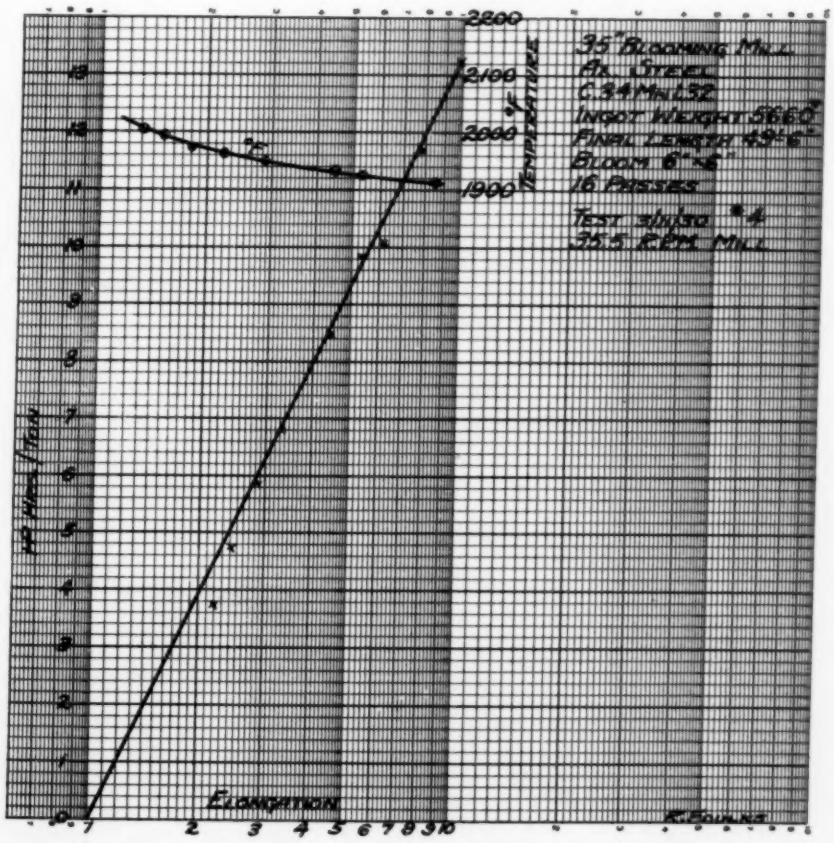


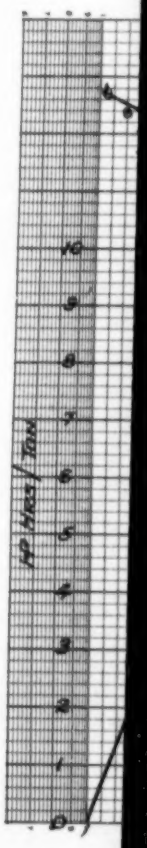
A.





Steel.	C	Mn	Cr	Ni.	Mo.	V.	Temp Range	Total n	HP Hrs/Ton Total n
4634	.46	.70	.80	1.82	.20		2070 - 1992	2.60	5.8
6120	.23	.72	.73	.25		.13	2080 - 1995	2.85	7.28

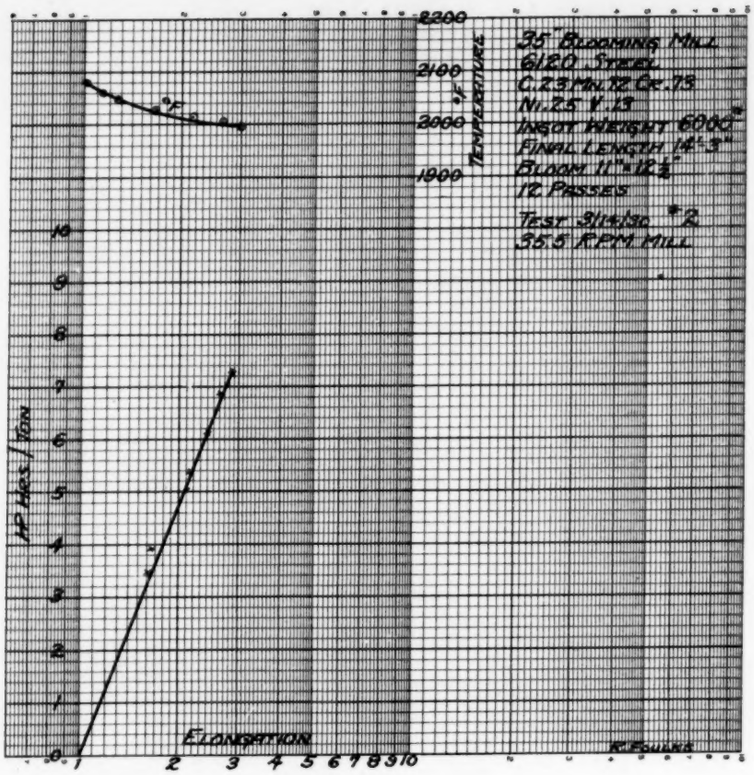




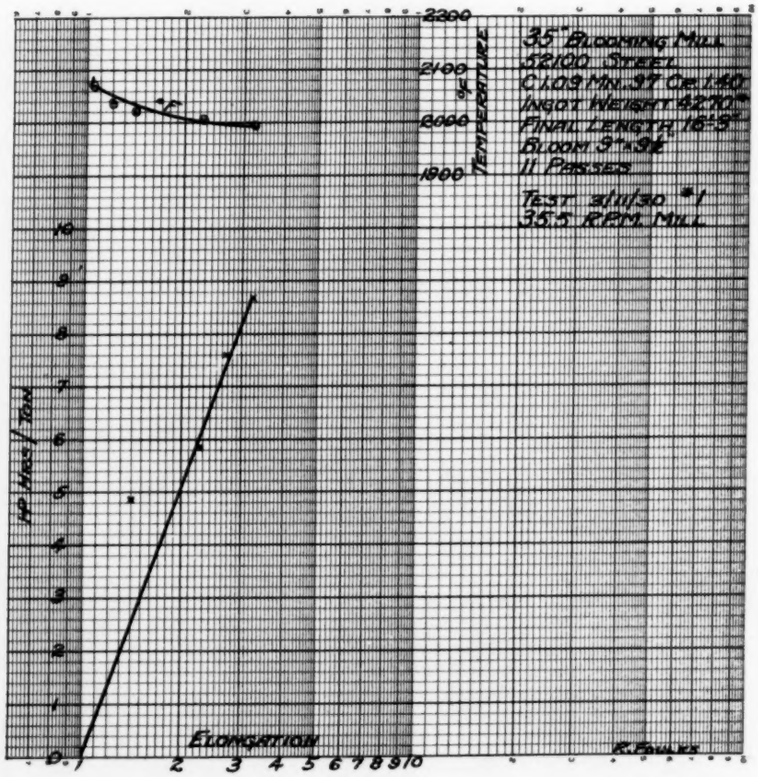
C.

FIG. 5.

B.



	Total n	HP Hrs/Ton Total n	Ingot	Product
	2.60	5.8	21"	11"x12½"
	2.85	7.28	22"	11"x12½"



D.

weighing from 4270# to 6000# which it rolled to 6" x 6", 7½" x 9", 9" x 9½" and 11" x 12½" blooms.

Figure 3 shows a 21" 5660# ingot and the cross-sections after each of the twelve passes required to roll it to 9" x 9½". It will be noted that because of the taper, a number of passes must be taken before the hot top is included in the uniform section produced by a pass. This rendered it impossible to analyse the earlier passes for horsepower seconds per cubic inch displaced. The curves that follow, therefore, give only the horsepower hours /ton of 2000# per elongation.

Figure 4 showing the power curves for various kinds of steel rolled in the Blooming mill indicates that there is no wide difference in power required to roll steel of different analyses.

The table in the center gives a resume of the power consumptions while 9" x 9½" blooms were rolled. The temperatures did not vary to any great extent, the elongations were almost the same in each case, and while the analyses differed, the variation in power was not as great as might have been expected. Since the curves are almost straight lines, the horsepower hours for elongations based upon an average length of five feet for the 21" ingot, check out surprisingly close. The extreme difference shown is only 1.2 horsepower hours.

Figure 5 shows two curves covering results obtained while 21" and 22" ingots were rolled to 11" x 12½" blooms. Here again we note but little difference in the power requirements. A comparison made on the basis of an elongation of 2.6 shows that the horsepower hours for the 6120 steel was 6.7 or only.9 horsepower hour more than was required for the 4634 steel.

Figure 5 also shows the results obtained while rolling 6" x 6" from 21" ingots in 16 passes. Although the curve shows 13.2 horsepower hours /ton for an elongation of 9.9, it shows only 5.6 horsepower hours for an elongation of 2.6. The last curve in this figure covers the rolling of high carbon chrome steel to 9" x 9½". Note that here the ingot was 19" diameter and that the power for an elongation of 2.6 was 7.2 horsepower hours. This indicates that the high carbon steels call for more power to roll than do those of lower carbon content.

Figure 6 shows one of the computation sheets used for analysing the mill end of a test. As the cylinder registered the pressures for the top passes alone, only the even numbered passes could be shown. The radii of the roll at the bottom of the passes were obtained by actual measurement. The heights of the steel before and after the passes were obtained from the slices cut from the ingots which were laid out. The mean proportionals "M" were used for calculating the projected area of contact with the roll. The mean proportionals were obtained by scribing arcs representing the bottom of the passes on sheets of tracing cloth, and the mating arcs were slid over each other until they overlapped by the amount of the reduction. The Means were then measured as were also the roll penetrations.

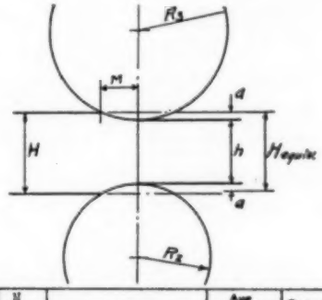
The top roll penetration "a" taken twice, and added to the height "h" of the steel in the pass, gave us the equivalent height "H" in the compression rate formula to be discussed later.

Figure 6a shows the pressures encountered while ten ingots were rolled to 6" x 6". The small table 6b at the bottom shows the magnitudes of the peak pressures reached during passes 10, 12, 14 and 16.

The average rolling pressures shown on the computation sheet are the averages of the 10 pressures for a pass, plus 27,000# for the weight of the top roll.

The two columns headed "curve points" were filled with the values we intended to use for plotting curves covering the resistance the steels offered to deformation. We found, however, that the average pressures did not yield enough points to permit of drawing smooth curves. It will, therefore, be necessary to analyse each pass for each ingot before these curves can be drawn.

When viewed from various angles, tests made only for the determination of powers required to roll



NEW ..... Old .....
Mill Rolls Used
Roll Material Steel Casting
Roll Dwg ES 582

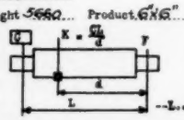
Bearings Pl. ✓ ..... T .....
Pl. Bg. Neck ϕ 20½ x 20 lg.
Area in bearing 410 □"
Length in bending ..10"...
R.B.Neck ϕ ..... x ..... lg.
Length in bending .....

Mill ..35"...
Test No. 5
Date 3-11-30
Steel AX
Product 6x6

Pass No.	Radius of roll bottom of pass Bot. R_1	Mid. R_2	Top R_3	Steel in this roll pass H	h	Total Red. H-h	M. Mean Prop. in.	W Width of Steel in pass in.	Proj Area Cont Lw. □"	Top Roll Penetration a	Equivalent Reduction 2a	Equivalent Hgt. of Bloom H + 2a	N Ave. R.P.M. Rolls	Calculated Compression Rate.	Ave. Rolling Pressure K	Curve Points # □" K/Mw	Temp. °F	
2		11 3/16	12 1/16	18 1/2	16 1/4	2 1/4							34.2					
4		11 3/16	12 1/16	15 5/8	13 1/4	2 3/4							33.82					
6		11 1/16	12 1/16	18 3/4	16 3/8	2 3/8	5.22	13 1/2	70.5	1.16	2.31	18.69	33.82	1.02	722200	10250	2001	
8		11 1/16	12 1/16	15 5/8	10 3/4	4 7/8	7.27	"	98.2	2.32	4.63	15.38	33.25	1.73	805190	8200	1980	
10		14 1/16	14 1/16	10 3/4	8 3/4	2	5.37	13 5/8	71.8	.963	1.93	10.68	32.5	1.71	752860	10450	1964	
12		14 1/16	15 1/16	10 1/4	8 1/4	2	5.37	9 1/8	50.3	.963	1.93	10.18	32.5	1.82	666800	13200	1953	
14		14 1/16	15 1/16	8 1/4	7 1/4	1	3.83	9 1/8	35.9	.465	.93	8.18	33.5	1.62	453840	12630	1934	
16		16 1/4	16 1/4	8	5 1/2	2 1/2	6.37	7 1/8	50.2	1.25	2.50	8.00	33.5	2.81	514980	10250	1920	
17				7 1/8	6	1 1/8		6					33.0					

FIG. 6.

Ingot ..... Size 21"
Test No. 5 Steel Ax Analysis C.34 Mn.62 P.035 S.04 Max. Bloom ..... Billet ..... Weight 5660 Product 6"x6" Mill 36"
Date 3-11-30 Start ..... Finish .....



Pass No.		2	4	6	8	10	12	14	16
Groove	B & M								
	N & T	1	1	2	2	3	4	4	5
d		23 7/8	23 3/8	44 15/16	44 15/16	63 3/8	79 1/4	79 1/4	93 1/8

Add 27000# to each Cf item to cover weight of top roll.

Piece No.	Pass 2 f=5.152			Pass 4 f=5.152			Pass 6 f=2.737			Pass 8 f=2.737			Pass 10 f=1.946			Pass 12 f=1.551			Pass 14 f=1.551			Pass 16 f=1.321		
	T	C	Cf	T	C	Cf	T	C	Cf	T	C	Cf	T	C	Cf	T	C	Cf	T	C	Cf	T	C	Cf
1		115000	592490	—	142000	791584	2038	220000	602240	2027	270000	738970	2005	345000	671870	1994	365000	566115	1983	252000	390852	1961	335000	442535
2		115000	592490	2060	145000	747040	2038	235000	643195	2016	265000	725845	2005	340000	661640	1994	375000	581625	1972	268000	395505	1961	342000	451782
3		110000	566720	2005	155000	798560	1994	250000	684250	1972	285000	780045	1961	350000	681100	1950	375000	581625	1938	260000	403260	1926	345000	455745
4	2080	105000	540960	2060	142000	731584	2038	285000	780045	2016	265000	725305	2005	340000	661640	1994	360000	558360	1972	240000	372240	1961	330000	435930
5	2149	115000	592480	2027	155000	798560	2016	250000	684250	2005	270000	738970	1983	365000	710290	1972	400000	620400	1950	265000	411015	1926	395000	521795
6	2060	110000	566720	2038	145000	747040	2016	240000	656880	2005	270000	738990	1994	350000	681100	1983	385000	597135	1961	245000	379995	1950	362000	478202
7	2038	125000	644000	2016	155000	798560	1994	270000	738990	1972	270000	738990	1961	375000	729750	1950	455000	705705	1902	305000	473055	1890	400000	528400
8	—	125000	644000	1972	175000	901600	1938	300000	821100	1914	320000	875840	1890	425000	827050	1878	460000	713460	1866	320000	496320	1854	410000	541610
9	2005	125000	644000	1983	175000	901600	1950	265000	725305	1914	323000	884051	1890	440000	856240	1878	505000	783255	1866	315000	488565	1854	405000	535085
10	2027	110000	566720	2005	170000	875840	1983	225000	615825	1961	305000	834785	1950	440000	778440	1938	445000	690195	1926	295000	457545	1914	370000	488770
Ave.	2045	115500	595056	2018	155900	803197	2001	254000	695198	1980	284300	778129	1964	373000	725858	1953	412500	639788	1934	275200	426885	1920	369400	487977

Distance L is constant for all passes.
Factor f varies for different passes, = $\frac{L}{d}$.
Pressure C is taken from strip Chart
Rolling Pressure K is total for pass = Cf
Fulcrum neck load F = K - C.
Temperature T is in °F. Taken from records.

The Comptometer operation consists of:-
1 - Multiplying values in "C" column by values "f" for each pass. = Cf
2 - Averaging all values in columns T, C. & Cf.

FIG. 6A.

Peak Loads.

Add 27000# to each Cf item to cover wgt. of top roll.

Piece No.	Pass 10 f=1.946			Pass 12 f=1.551			Pass 14 f=1.551			Pass 16 f=1.321			Pass
	T	C	Cf	T	C	Cf	T	C	Cf	T	C	Cf	T
1		370000	720020		402000	623502		282000	437382		390000	515190	
2		370000	720020		420000	651420		275000	426525		375000	495375	
3		415000	807590		455000	705705		325000	504075		420000	554820	
4		370000	720020		395000	612645		275000	426525		370000	488770	
5		390000	758940		425000	659175		290000	449790		415000	548215	
6		375000	729750		420000	651420		285000	442035		415000	548215	
7		402000	782292		495000	767745		335000	519585		450000	594450	
8		440000	856240		495000	767745		340000	527340		435000	574635	
9		455000	885430		525000	814275		335000	519585		440000	581240	
10		410000	797860		470000	728970		318000	493218		400000	528400	
Ave.		399700	777816		450200	698260		306000	474606		411000	542931	

FIG. 6B.

steel, when conducted on the magnitude that was reached during our program, would early become commonplace affairs if they were not made to yield something in addition that would increase the meagre fund of information we have on rolling steel.

There is but little data available on the pressures encountered in different mills. Data on the coefficients for plain bearing neck friction is sadly lacking. One must search long and carefully to find a method for determining the torque required to take care of all of the work entering into the displacement of the steel. And finally, the present method of finding the resistance the steel offers to deformation by the compression rate formula, as now constructed, involves too many steps to permit of quickly analysing a number of roll passes in a short period of time.

Figure 7 shows the compression rate formula as now constructed and the four steps one must take before the rate is definitely known. An inspection will show that while step #1 is not necessarily required for arriving at the Rate, it must be taken when the length of contact is obtained; or another calculation involving the sine of α and the radius R must be substituted. However, since step one is usually taken when the rate is found, it is included in the figure.

Your speaker has long been using a simpler construction of the compression rate formula which

stood us in excellent stead when we analysed our tests at Canton. This formula requires but two steps, and these can be reduced to a single slide rule operation which, when completed, will permit one to be on his way.

Figure 8 shows this formula which assumes the shape: $\frac{.105\ N\ \sqrt{Rr.}}{H}$ Here N is the roll speed in R.P.M. R the roll radius in inches, r, the reduction in inches, total; or equivalent; depending upon whether the two roll diameters are alike, or whether they are different; and H is the height of the steel before the pass. H must be taken as the equivalent height as mentioned before if the roll diameters are not the same.

This formula is based upon the premise that since the roll has its nominal radius only once in its lifetime, and this radius grows smaller with each roll dressing, the angle of contact α need at no time be calculated with extreme accuracy since it also changes as the roll grows smaller.

If we, therefore, calculate the Rate with the length of the chord "ab" instead of the arc "ab", we will commit no grave error in the long run. Moreover, since we can also use the chord for calculating the projected area of contact, we immediately compensate for what slight error results in the angle α if the chord is used instead of the arc.

This will at once become apparent if you consider that for an angle of 30° and roll diameter of 40" the difference is only .006 x 20" or ⅛". For a roll diameter of 20" this difference is only .006 x 10" or 1/16", a trifling amount indeed.

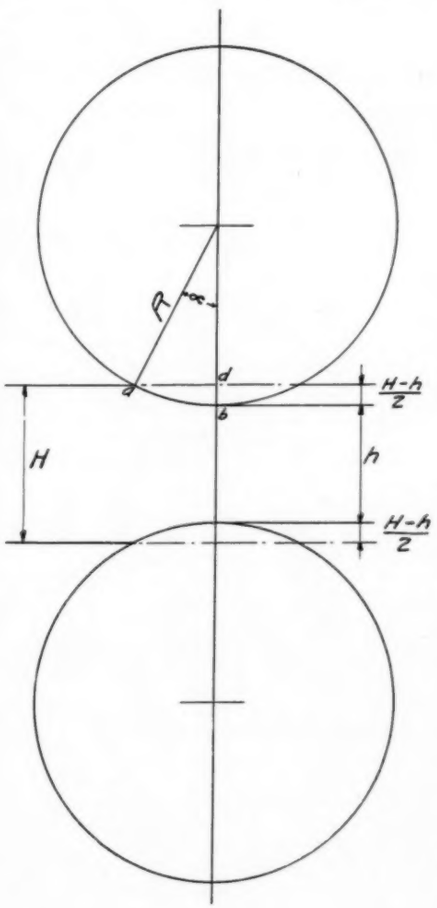
Figure 8a shows a computation sheet covering the rolling of 21" Krupp ingots to 9" x 9½" blooms. The sheet shows the rates as calculated by the two formulas. You will at once see that very little difference exists in the results obtained. Figure 8b also shows the loads encountered during this test, and Figure 8c shows the peaks reached during the last two passes.

In order to arrive at the Net horsepower second per cubic inch displaced in the Blooming mill, it was of course essential that we deduct neck friction losses with the other losses before the Net horsepower rate for a pass was known.

There was, however, no data available on the coefficient of plain bearing neck friction, so we undertook a test to determine it.

Figure 9 shows that the arrangement of the mill was such that by disconnecting the middle roll, and blocking up the top roll carrier from it, we could clamp the necks of the top roll with cylinders, and create a condition that was similar to that of rolling, but without steel in the pass.

The diagram at the right shows how two cylinders were connected with the test pump and record-



N = R.p.m of rolls.

t = Time in seconds to pass thru arc ab.

ad = Hor. proj. length of contact.

$$ad = \sqrt{R^2 - \left(R - \frac{H-h}{2}\right)^2} \qquad \text{(Step 1.)}$$

$$\frac{R - \frac{H-h}{2}}{R} = \text{Cosine } \alpha \qquad \text{(Step 2.)}$$

Number of degrees in angle α taken from tables. (Step 3.)

$\frac{\alpha}{360}$ = Number of revolutions to pass thru arc ab.

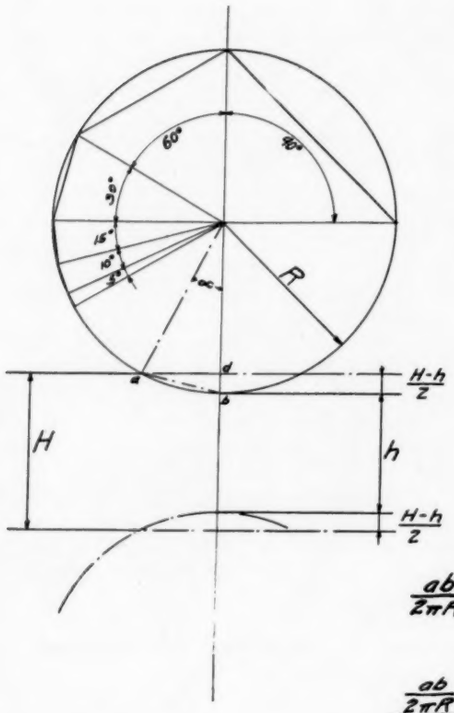
$\frac{N}{60}$ = Number of revolutions roll makes per second.

$$\frac{\frac{\alpha}{360}}{\frac{N}{60}} = t, \text{ the time in seconds to pass thru arc } ab.$$

$$\frac{H-h}{H \cdot t} = \text{Compression Rate.}$$

$$\frac{H-h}{H \cdot t} = \frac{H-h}{H \times \frac{\frac{\alpha}{360}}{\frac{N}{60}}} = \frac{(H-h) \cdot \frac{N}{60}}{H \cdot \frac{\alpha}{360}} \qquad \text{(Step 4.)}$$

FIG. 7



Angle	Length of Arc		Length of Chord.		Lgth Arc − Lgth Chord.
90°	1.5708 R	−	1.4142 R	−	.1566 R
60°	1.0472 R	−	R	−	.0472 R
30°	.5236 R	−	.5176 R	−	.0060 R
15°	.2618 R	−	.2610 R	−	.0008 R
10°	.174533 R	−	.174311 R	−	.000222 R
5°	.087266 R	−	.087238 R	−	.000028 R
1°	−				.000000$\frac{1}{3}$ R

$$ab = \sqrt{R(H-h)} \cdot \sqrt{Rr} \qquad \text{(Step 1.)}$$

Substituting the length of the chord for the length of the arc, we can solve for the compression rate $\frac{H-h}{H \times t}$ as follows:-

$\frac{ab}{2\pi R}$ = Part of the circumference in the arc; also the number of revolutions require to pass thru the arc.
(As long as this quotient is less than .083, the angle α is under 30°)

$$\frac{\frac{ab}{2\pi R}}{\frac{N}{60}} = \frac{60\,ab}{2\pi RN} = \frac{ab}{.10472\,RN} = t, \text{ time in seconds to pass thru arc } ab.$$

Using r instead of H-h in compression rate formula, $ab = \sqrt{Rr}$, and

$$\text{Compression Rate } \frac{H-h}{H \cdot t} = \frac{r}{H \cdot \frac{\sqrt{Rr}}{.105\,RN}} = \frac{\sqrt{r} \cdot .105\,\sqrt{R}\,RN}{H \cdot \sqrt{R}\sqrt{r}} = \frac{.105\,N\sqrt{Rr}}{H} \qquad \text{(Step 2.)}$$

FIG. 8.

Mill Rolls Used NEW ..... Old ...K.....
Roll Material Steel Cstg.
Roll dwg. E3589

Bearings Pl. ↙ ..... T .....
Pl. Bg. Neck ϕ 20½" x 20" lg.
Area in bearing ..... 0"
Length in bending .....
R.B.Neck ϕ ... x ..... lg.
Length in bending .....

Mill 35"
Test No. 4
Date 3-11-30
Steel Krupp
Product 9" x 9½"

Pass No.	Radius of roll bottom of pass Bot. R_1	Mid. R_2	Top R_3	Steel in this roll pass H	h	Total Red. H-h	M. Mean Prop. in.	w Width of Steel in pass in.	Proj Area Cont Lw. B"	Top Roll Penetration	Equivalent Reduction 2a	Equivalent Dist. of Rolls 2a	N Ave. R.P.M. Rolls	Calculated Compression Rate.	Rolling Pressure K Ave. 10	Curve Points # D" K / Mw	Temp. °F	
2		11 9/16	12 9/16	18½	16 9/16													
4		11 9/16	12 9/16	15 5/16	13 9/16									$\frac{H-h}{H \times t}$				
6		11 9/16	12 9/16	17 7/8	16¼	1 5/8	4.35	13¼	57.6	.763	1.53	17.78	34.0	.865	703040	12200	2025	
8		11 9/16	12 9/16	15 5/16	13½	2 1/16	4.88	13¼	64.8	.99	1.98	15.48	33.5	1.12	772800	11900	2007	
10		14 1/16	14 9/16	10 7/16	8¼	2 1/16	5.58	13¼	77.5	1.063	2.13	10.63	33.0	1.79	810270	10440	1991	
12		14 9/16	15 9/16	11	9	2	5.38	9¼	51.3	.963	1.93	10.93	33.0	1.71	593120	11550	1997	
			R				$\sqrt{Rr}$				r	H	N	$.105\,N\sqrt{Rr}/H$				
							4.38		58.2		1.53	17.78		.88				
							4.98		66.2		1.98	15.48		1.63				
							5.62		78.0		2.13	10.63		1.83				
							5.44		51.7		1.93	10.93		1.73				

Computation Sheet 4a

FIG. 8A.

Test No. 4 Steel Krupp Analysis C.12 Mn.37 Cr.14 N. 406 Ingot ✓ Bloom ..... Billet ..... Size 21 Weight 5660 Product 9x9½ Mill 35" Date 3-11-30 Start ..... Finish .....

Pass No.		2	4	6	8	10	12
Groove	B & M						
	M & T	1	1	2	2	3	4
d		23 3/8	23 3/8	44 15/16	44 15/16	63 3/16	79 1/4

K = C/d, f, d, L, L = 123"

Add 27000# to each Cf item to cover weight of top roll

Piece No.	Pass 2 f=5.152			Pass 4 f=5.152			Pass 6 f=2.737			Pass 8 f=2.737			Pass 10 f=1.946			Pass 12 f=1.551		
	T	C	Cf	T	C	Cf	T	C	Cf	T	C	Cf	T	C	Cf	T	C	Cf
1	—	100000	515200	—	135000	695520	2060	235000	643195	2049	270000	738990	1994	365000	710290	1961	37500	581625
2	—	135000	695520	1983	165000	850080	1972	270000	738990	1961	300000	821100	1950	425000	827050	1938	390000	604850
3	—	125000	644000	2027	160000	824320	2005	265000	725305	1994	270000	738990	1972	375000	729750	1961	340000	527340
4	—	110000	566720	2060	145000	747040	2038	235000	643195	2016	250000	684250	2005	375000	729750	1994	295000	457545
5	—	100000	515200	2093	140000	721280	2070	235000	643195	2038	260000	711620	2027	345000	671370	2016	300000	465300
6	2110	115000	592480	2093	145000	747040	2060	235000	643195	2038	260000	711620	2027	370000	720020	2016	315000	488565
7	—	125000	644000	2060	160000	824320	2027	270000	738990	2005	295000	807415	1994	382000	743372	1983	330000	511830
8	—	125000	644000	2016	145000	747040	2005	235000	643195	1994	270000	738990	1983	355000	690830	1972	315000	488565
9	—	140000	721280	—	160000	824320	1994	260000	711620	1983	275000	752675	1972	365000	710290	1961	335000	519585
10	—	115000	592480	2049	150000	772880	2016	230000	629510	1994	275000	752675	1983	345000	710290	1972	315000	488565
Ave.	2110	119000	613088	2047	150500	775376	2025	241000	676039	2007	272500	745833	1991	372200	724301	1977	331000	513381

FIG. 8B.

ing gauge. The mill was run with the bottom and top rolls in motion, and pressures of different intensities were pumped up and released after each power reading was taken.

Figure 10 shows the loads imposed upon the necks of the top roll, and the net horsepower required to overcome the neck friction. The calculated coefficient of friction ranged from .0324 to .061 with an average of .041 for the fourteen loads. The necks were water cooled, but no grease was added to what was in the bearing boxes when the mill was set up.

The average coefficient appears low. This may be attributed to the fact that it took time to build up the various pressures. It is likely that when the load is applied suddenly, as when the steel enters a pass, the grease film is broken down and the friction is somewhat higher than that shown by the clamped neck test. Be that as it may, we used the coefficient .041 when we calculated the neck friction horsepower given in the table, Figure 10a. This table covers the rolling of a 21" C.W. ingot to 9" x 9½" bloom.

Peak Loads.

Piece No.	Pass 10 f=1.946			Pass 12 f=1.551		
	T	C	Cf	T	C	Cf
1		385000	749210		405000	628155
2		485000	943810		450000	697950
3		425000	827050		370000	573870
4		410000	797860		350000	542850
5		360000	700560		320000	496320
6		395000	768670		345000	535095
7		400000	778400		360000	558360
8		375000	729750		340000	527340
9		380000	739480		350000	542850
10		410000	797860		360000	558360
Ave.		402500	783265		365000	566115

FIG. 8C.

As stated earlier in the paper, the entire rolling operation could not be analysed for horsepower seconds / cubic inch because it required seven passes before the hot top was included in the uniform section. The table, therefore, shows this data for passes 8, 10 and 12 only. Since the horsepower seconds / cubic inch are not high, it is probable that the coefficient .041 is not far from the true value.

It is interesting to note that Dr. Puppe's tests on a Cogging Mill show horsepower second values that range from 1.97 to 4.14 in one case, and from 2.07 to 4.07 in another. These tests are described in Volume II, 1910 Carnegie Scholarship Memoirs,

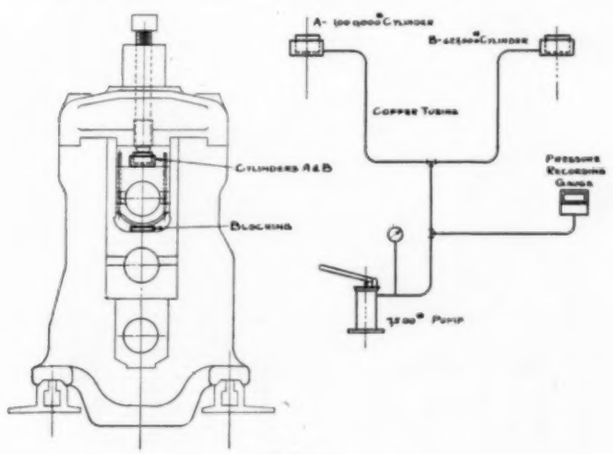
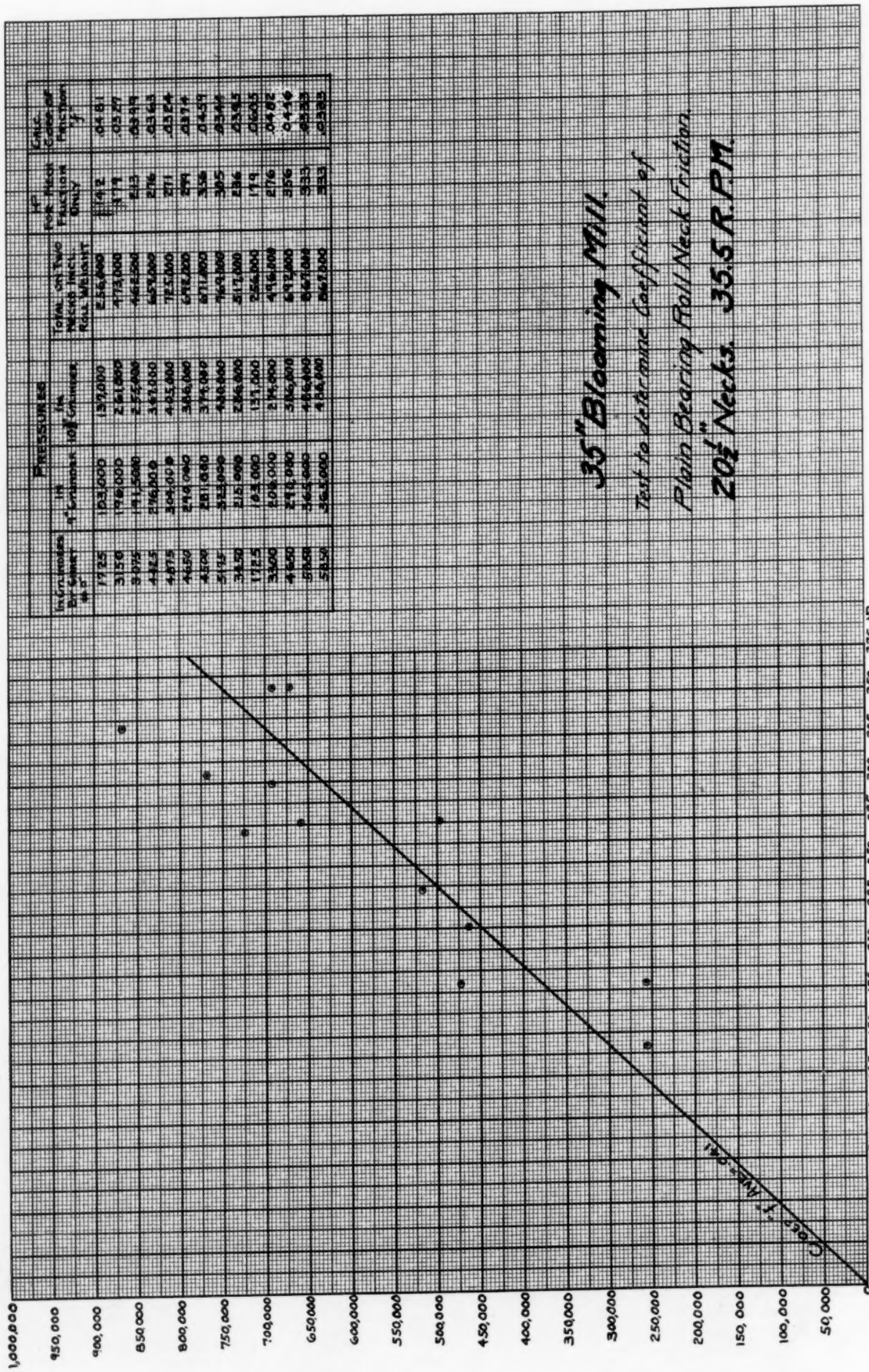


FIG. 9.



Pressures				HP	
In Grooves By Sheet ± 5%	In ± 5% ℔ Grooves	In ± 10% ℔ Grooves	Total on Two Necks Incl. Roll Weight	For Neck Friction Only	Calc. Coef. of Friction ± 5%
1725	103,000	137,000	136,000	142	.0481
3150	178,000	251,000	173,000	171	.0527
3975	141,500	254,000	466,500	513	.0349
4325	236,000	361,000	650,000	716	.0363
4675	304,000	445,000	715,000	771	.0374
4650	274,000	346,000	692,000	691	.0374
4500	281,000	376,000	671,000	658	.0459
5150	353,000	476,000	749,000	805	.0344
3450	215,000	286,000	617,000	686	.0345
1725	93,000	131,000	254,000	119	.0603
3300	208,000	296,000	496,000	276	.0482
4450	270,000	386,000	692,000	376	.0446
5100	365,000	486,000	867,000	533	.0389
5850	364,000	456,000	867,000	523	.0385

FIG. 10

pages 271 to 304. They cover the rolling of 19.7"x15.7"x5.4' 5400# ingots to 5¾"x7½" blooms in 17 passes. The mill was a 43.31" 2H Steam Engine driven Reversing unit. The complete report is published in English, but all measurements are given in metric terms and must be converted by the reader.

35"- 3 High Blooming Mill.

Steel C.W. Analysis C..12 Mn. 1.85

Ingot #9 Size 21"¢ Weight 5660 Volume 25,000 cu.in.

Pass No	Temp °F	Total HP Sec. per Pass	Time of Pass Sec.	HP Rate per Pass	Calc. Drive And Pinion Losses HP	Rolling Pressure And Calc. Neck Friction HP	Net Rolling HP	Net HP Sec.	Volume Displ. Cu. In.	HP Sec. per Cu. In.
1		2135	1.6	1335						
2		4210	1.8	2340						
3		2960	1.9	1560						
4		8370	2.2	3800						
5		2415	1.6	1510						
6	2065	6170	2.1	2940						
7		4250	2.2	1930						
8	2049	10900	2.6	4190	507	834418 3.95	3288	8550	3060	2.8
9		11000	3.0	3660						
10	2022	12350	3.2	3860	468	609300 383	3009	9630	4367	2.2
11		10250	3.8	2700						
12	1983	12100	4.2	2880	349	602593 286	2245	9430	3500	2.7

FIG. 10A.

Referring again to the table, the horsepower rates for the passes (listed in column five) are those actually required by the mill while rolling. They, therefore, do not include the torque of the motor at the instant the steel entered a pass, but they do include the drive, pinion and neck friction horsepower. These three items were deducted before the Net Rolling Horsepower rate (column 8) were known. The drive loss was taken at 6½% of the total input into the drive pinion, the mill pinions were calculated to consume 6% of the horsepower they transmitted, and the neck frictional losses, as stated before, were calculated on the basis of .041 for the coefficient of neck friction.

The Net Rolling Horsepower with the time of a pass in seconds yield the Net Horsepower Seconds in column nine, and these, when divided by the actual volume displaced in cubic inches, give the horsepower seconds / cubic inch in column eleven.

Summarizing the results of the Blooming Mill tests, the following data has been obtained in addition to the horsepowers required to roll steel of different analyses:

We learned that rolling pressures as high as 1,135,000# are encountered while rolling up to 22" diameter ingots in a 35" mill.

The coefficient of friction for 20½" necks on plain bearings is about .041 with the probability that as lubrication is broken down the coefficient may approach .06 or more.

A simpler construction of the Compression Rate formula is offered to those who must at times analyse roll passes quickly.

Twenty-two check calculations made to determine the length of lever arm on which the rolling pressure is considered applied when the torque for the actual displacement is obtained show values ranging between .500 to .877 (with an average of .66) of the horizontal projected length of contact between roll and steel. The average of fifteen values ranging from .612 to .877 was .723, and the average of thirteen very consistent values ranging from .612 to .800 was .700. Of these thirteen values eight were above .65 and only five were below.

The average .70 is the same as that used by Mr. J. D. Kellar in his article "Rolling Mill Calculations" which appeared in the April, 1927, issue of the Iron & Steel World.

Figure 11 shows the arrangement of the 28" 3H Bar mill which serves more as a breakdown stand for the 22" mills than as a producer of finished sizes.

We were, however, able to run several tests on the first stand and obtain the power consumption while rolling 9" x 9½" blooms to 6" x 7⅞" and 6¼" x 5".

This unit, including pinions and drive, is fully Timken Bearing equipped and no power comparisons could be obtained on it.

Figure 12 shows a typical power curve for rolling 6" x 7⅞" in four passes. Figure 12a shows one full computation sheet for one test, and the ends of four

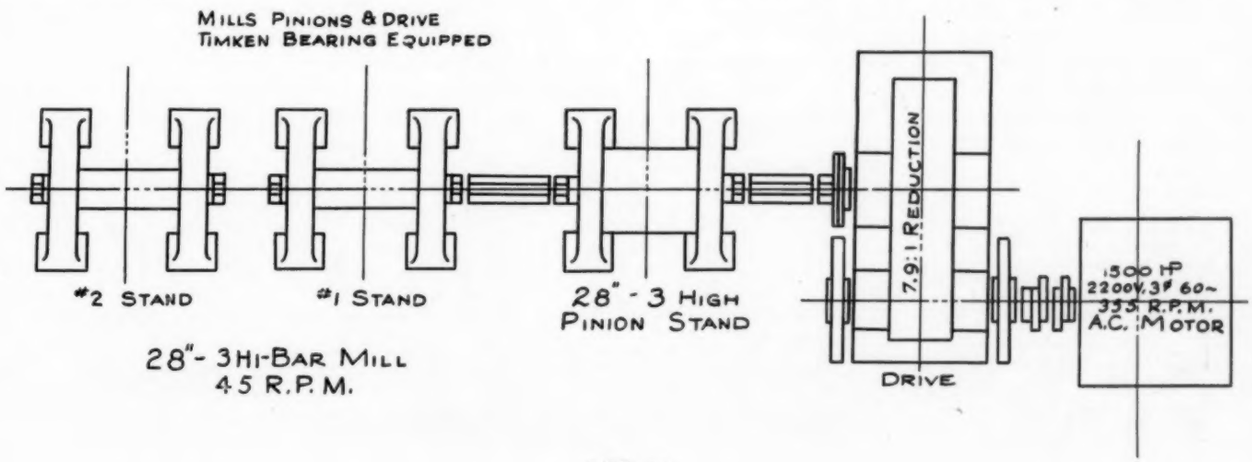


FIG. 11.

other sheets. Only the two top passes could be analysed. The speeds and reductions were the same for all steels rolled. The data on the full sheet, therefore, applies to all others.

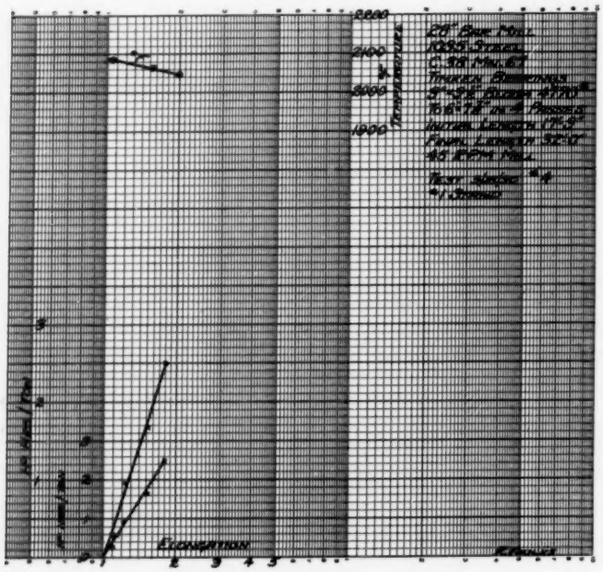


FIG. 12.

It will be noted that the rolling pressures for the three carbon steels grow lower as the temperature rises, and that the C.W. sheet which shows the highest temperature records the lowest pressures.

Test No. 3 shows the highest pressures notwithstanding the temperatures were nearly 2100° F. The power required for an elongation of 1.8 averaged around 2.5 horsepower hours /ton.

Figure 13 shows results while rolling the 6¼" x 5" blooms in six passes, and Figure 13a is the computation sheet applying to same. The temperatures were quite high and the pressures in keeping with those shown for the C.W. steel in Figure 12a.

The power consumption for the first four passes again averages about 2.5 horsepower hours /ton for an elongation of 1.8.

Figure 14 shows the four stand 22" 3 and 2H Bar mill. This unit receives steel after it has been broken down in the 28" mill and rolls it to a variety of sizes of squares, rounds, and flats. The drive, pinions, and number two stand are Timken bearing equipped; and although we have the roller bearings for the other stands, they were operating on plain bearings during our first tests.

This at first appeared to be an extremely undesirable condition to analyse, but upon plotting our first curves we found they disclosed such pronounced breaks in the power lines when the steel entered a plain bearing mill, as to remove all doubt concerning the savings that is effected by the use of roller bearings.

Figure 15 shows this point very clearly. The first curve (a) covering the rolling of 9" x 9½" to 5¾" diameter round in seven passes shows the power line for the first four passes made on the bloom in the 28" Timken mill. The steel was then transferred to No. 3 stand of the 22" mill where it received two passes, on plain bearings, after which it was finished to 5¾" diameter in one pass on plain bearings in No. 4 stand. The line has an abrupt rise the instant the steel entered the plain bearing mills. As the line for the roller bearing passes is quite straight, it is reasonable to assume that it would have continued in the same direction if the 22" stands had had roller bearings, and the horsepower hours /ton would have been around 4 instead of 7½ as the curve shows.

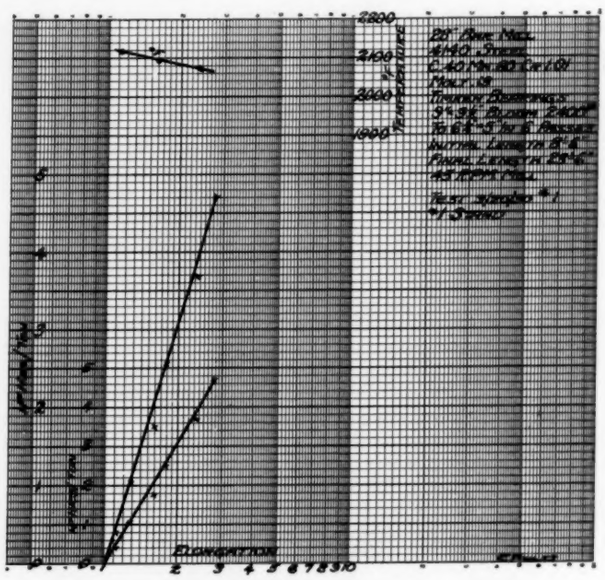


FIG. 13.

Curve (b) shows the conditions while 3¼ squares were rolled from 7½" x 9" blooms in nine passes. In this instance the steel again received four passes in the 28" Timken mill, from which it went to No. 1 stand of the 22" where it received one pass on plains. From there it went to No. 2 stand of the 22" where it received two passes on Timkens, and finally to 3 and 4 stands where it received one pass in each on plains.

Mill Rolls Used New / Old ...
Roll Material Steel Casting
Roll Dwg. E.S.2087

Bearings Fl. ... T. ...
Fl. Bg. Neck ϕ ... x ... lg.
Area in bearing ... sq.
Length in bending ...
R.B. Neck ϕ ... x ... lg.
Length in bending ...

	Mill 28" #1	Mill 28" #1	Mill 28" #1	Mill 28" #1	Mill 28" #1
	Test No. 1	Test No. 2	Test No. 4	Test No. 3	Test No. 5
	Date 3-18-30.	Date 3-18-30.	Date 3-18-30.	Date 3-18-30.	Date 3-18-30.
	Steel 1035	Steel 1040	Steel 1035	Steel 1315	Steel C.W.
	Product 6 x 7⅞	Product 6 x 7⅞	Product 6 x 7⅞	Product 6 x 7⅞	Product 6 x 7⅞
	.38C. .67 Mn.	.39C. .68 Mn.	.38C. .67 Mn.	.16C. 1.45 Mn. .25 Mo.	.12C. 1.85 Mn.

Pass No.	Radius of roll bottom of pass Ins.	Rad.	Top	Steel in this roll pass H	h	Total Red. Ins.	Mean Temp.	Weight of Steel in pass lbs.	Proj Area Cont. sq. in.	Top Roll Pressure	Accumulat Reduction	Accumulat Elongation	# Revs. R.P.M. Rolls	Calculated Compression Ratio.	Rolling Pressure K Ave 5	Curve Prints K	Temp °F	Rolling Pressure K Ave 5	Curve Prints K	Temp °F	Rolling Pressure K Ave 5	Curve Prints K	Temp °F	Rolling Pressure K Ave 5	Curve Prints K	Temp °F	Rolling Pressure K Ave 5	Curve Prints K	Temp °F
	R1	R2	R3																									
2		10⅝	10¾	9	7⅛	1⅞	3.96	9	35.5	.75	1.5	9.00	45	2.13	471000	12050	2049	435500	12250	2045	399400	11250	2086	466800	13150	2086	318500	8980	2143
4		11⅜	11½	7⅛	6	1⅞	3.76	7⅛	29.5	.625	1.25	7.25	45	2.49	455000	15400	2036	448500	15200	2036	414500	14050	2064	476000	16150	2067	332000	11250	2166

FIG. 12A.

If all of the rolling had been done on roller bearings the power line would have dropped considerable for the entire 22" unit.

The last curve (c) covers the rolling of 7½" x 9" High Carbon Chrome blooms to 3¾" rounds in nine passes; four in the 28" Timken mill, and five in the 22" mill. The first pass in the 22" mill was made in No. 1 stand which had plain bearings, the next two in No. 2 stand which had Timkens, and the last two were made one each in Nos. 3 and 4 plain bearing stands. It is easily possible to trace the tendency of the curve to have a flatter slope wherever the steel is in a roller bearing mill.

Mill Rolls Used NEW ..... Old ...✓.....
Roll Material Steel Cstg.
Roll dwg ES-2057

Bearings Pl. ..... T ✓.....
Pl. Bg. Neck ϕ ..... x ...lg.
Area in bearing ..... □"
Length in bending .....
R.B.Neck ϕ ..... x .....lg.
Length in bending .....

.40 C
.60 Mn.
1.01 Cr.
.19 Mo.

Mill 28" #1
Test No. 6
Date 3-20-30
Steel 4140
Product 6½ x 5

Pass No.	Radius of roll bottom of pass Bot. R_1	Mid. R_2	Top R_3	Steel in this roll pass H	h	Total Red. H-h	M. Mean Prop. in.	w Width of Steel in pass in.	Proj Area Cont Nw. n"	Top Roll Penetration	Equivalent Reduction 2a	Equivalent hgt. of steel h + 2a	N Ave. R.P.M. Rolls	Calculated Compression Rate.	Rolling Pressure K Ave. B	Curve Points # D" K/Nw	Temp. °F
2		10 11/16	10 5/16	9	7½	1.50	3.94	9	35.5	.75	1.5	9	45	2.13	334500	9440	2114
4		11 3/16	11 11/16	7½	6	1.25	3.75	7⅞	29.5	.625	1.25	7.25	45	2.49	316700	10740	2101
6		11 15/16	12 3/16	5¾	5	.75	3.02	6¼	18.9	.375	.75	√.75	45	2.49	274100	14520	2075

FIG. 13A.

Figure 14 shows that the drive and pinions are equipped with Timkens. These require practically no power to operate, at least so little that we could not measure it with any reliability. We knew that the light loss of either mill setup could be obtained with reasonable accuracy. There, therefore, remained only the question of plain bearing neck friction which could not be calculated without a correct value for the coefficient of friction.

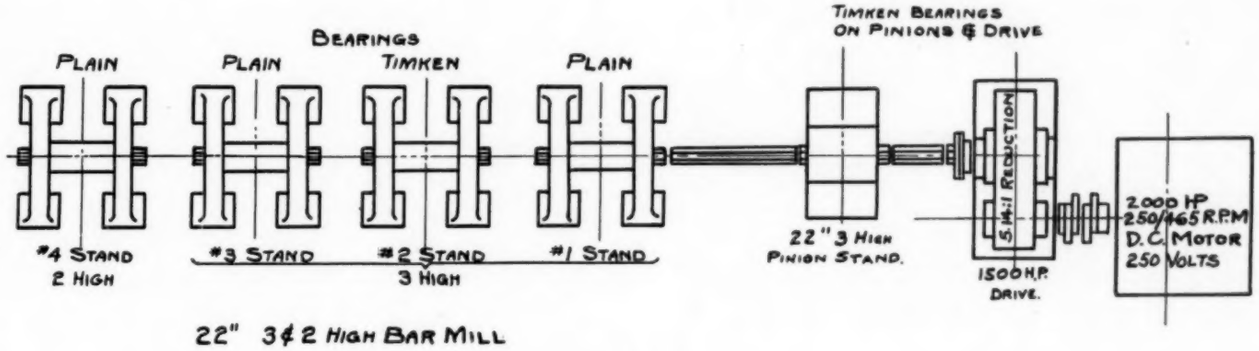


FIG. 14.

We, therefore, ran a neck friction test on No. 1 stand (which had plain bearings in it) before it was torn down and changed to Timkens for the comparative power test.

Figure 17 shows that since the top roll was already supported with liners on the middle roll rider, it merely entailed disconnecting the middle roll and installing the two hydraulic cylinders in the mill. These cylinders had 300,000# and 200,000# capacity at 12,000# /□" on the plungers.

Pressures of various intensities were pumped up as quickly as possible with the top and bottom rolls

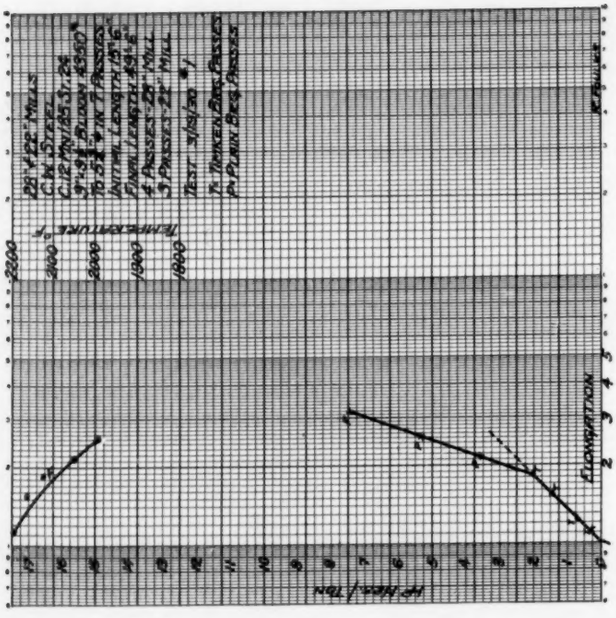
Figure 16 shows curves for the rolling of 3¼ squares, 4" rounds and 10" x 1⅜" flats in the two units.

Curves (a) and (b) show the tendency of the curves to rise abruptly when the steel enters the 22" plain bearing mills and to fall when it enters the roller bearing stand. Curve (c) also shows this condition.

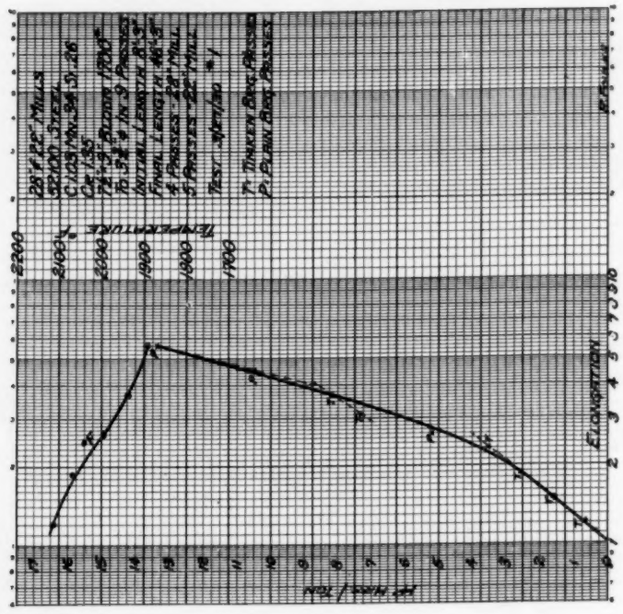
Here the steel was given 10 passes in the 28" Timken mill, one in the 22" Timken stand and finally four in the 22" plain bearing stands.

Curves a, b and c, Figure 16, show that if the rolling had all been done on roller bearings, the ultimate power requirements would have been considerably lower.

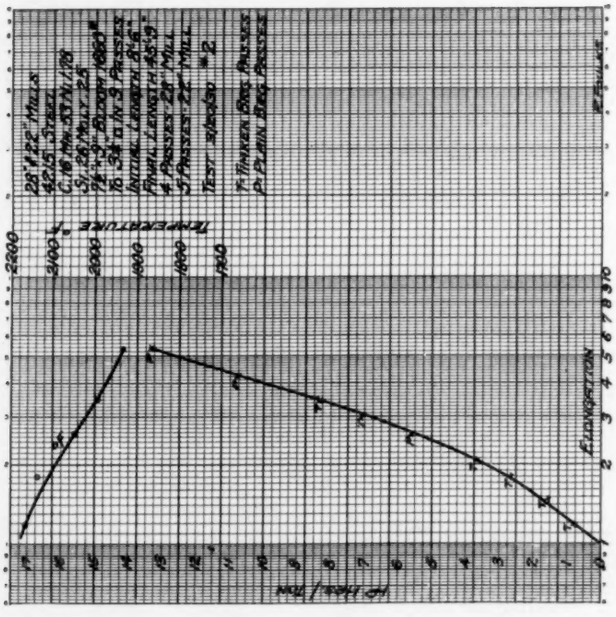
In order to arrive at an actual comparison between the power required to roll steel on both types of bearings, we next decided to set up two stands of 22" mill; first on Timkens, and then on plains, and roll 8" x 9" blooms to 2 11/16 squares in fifteen passes. The rolls available for both tests were alike except for slight difference in their diameters. It was the intention to analyse all results very carefully and to separate all losses in the complete units in order to see if the power required for actual displacement was the same.


28"-22" Mills
C.N. Steel
C.12/Mn/35/.26
Test #1 of 3
Initial Length 49'-6"
Final Length 49'-6"
4 Passes 28" Mill
5 Passes 22" Mill
Test #1 of 3
T. Taken Beg. Passes
P. Plain Beg. Passes
Temperature °F
Elongation
Ft. Lbs./Ton

A

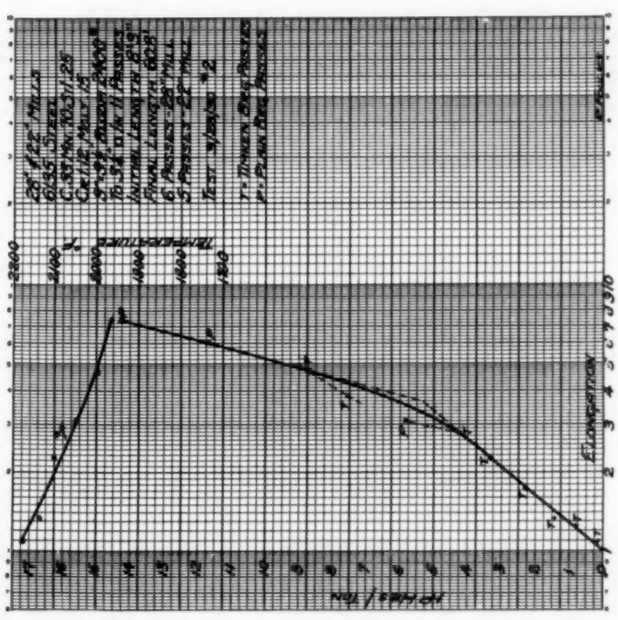

28"-22" Mills
42.50 Steel
C.18/Mn/.80/1.05
Si.20/Mo.25
Initial Length 49'-6"
Final Length 49'-6"
4 Passes 28" Mill
5 Passes 22" Mill
Test #2 of 3
T. Taken Beg. Passes
P. Plain Beg. Passes
Temperature °F
Elongation
Ft. Lbs./Ton

B.

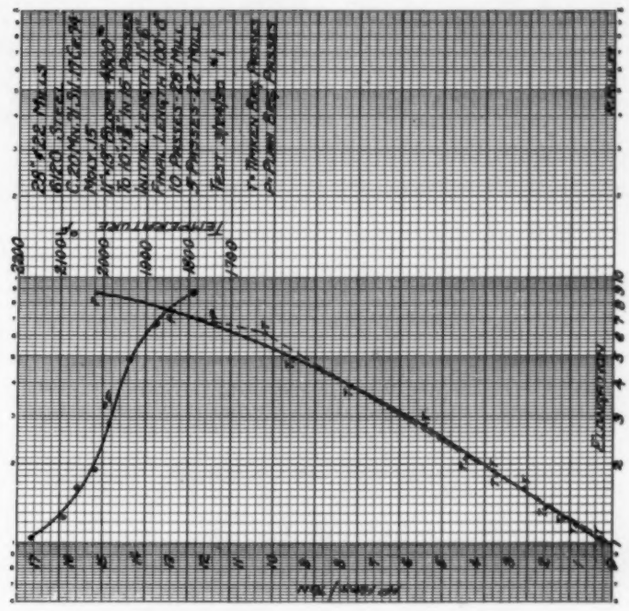

28"-22" Mills
42.50 Steel
C.18/Mn/.80/1.05
Si.20/Mo.25
Initial Length 49'-6"
Final Length 49'-6"
4 Passes 28" Mill
5 Passes 22" Mill
Test #3 of 3
T. Taken Beg. Passes
P. Plain Beg. Passes
Temperature °F
Elongation
Ft. Lbs./Ton

C.

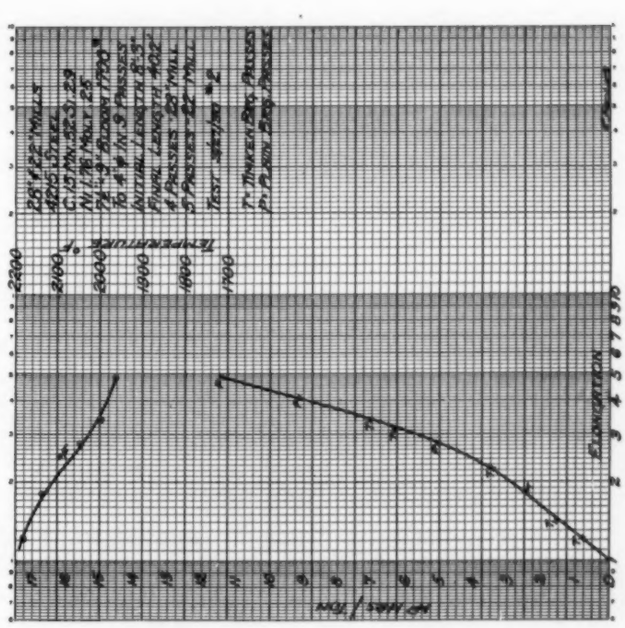
FIG. 15.



A.



C.



B.

FIG. 16.

in motion and held until the power readings were taken, and then released.

Figure 17a shows the pressures that were applied and the Net horsepower required to overcome the neck friction. As the mill had been idle for several days, the first four readings showed very high coefficients and these were thrown out.

The coefficients for the remaining twenty readings ranged from .055 to .105, the average being .071. This average was later used in the neck friction loss calculations for the comparative power tests on the 22" mills.

The power curves for the four different speeds used in the comparative tests are shown in Figures 20, 21, 22 and 23. In each figure, curve (a) shows the horsepower hours /ton for the plain bearing mills, and curve (b) shows those obtained for the roller bearing mills. Curve (c) is a composite sheet giving the curves shown in (a) and (b) in order that a comparison in the power requirements may be obtained at a glance. It can at once be seen that the plain bearing mills required from 64% to 93% more power than did those rolling on Timkens. The curves also permit of comparing the manner in

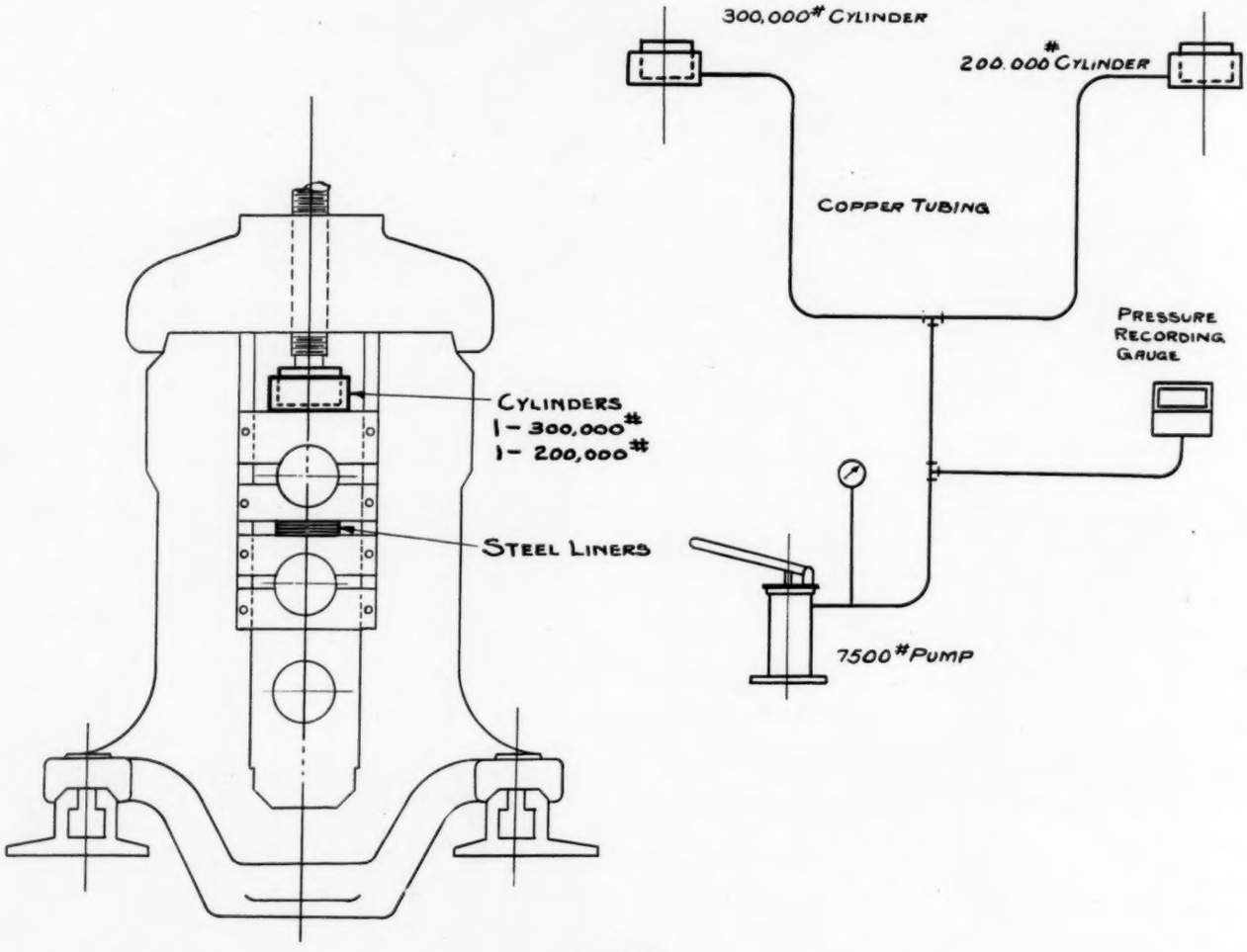


FIG. 17.

During these tests we rolled 46 8" x 9" so-called scrap blooms to 2 11/16" squares in fifteen passes. The blooms were all quite uniform in length, and of uniform analysis, the latter being around .46 C., .67 Mn., 3.5 Ni.

The speeds of the mills were changed from time to time in order to learn to what extent the power requirements responded to a change in roll speed. In the majority of cases, five blooms were rolled at each speed, although in several instances only three were used.

Figure 18 shows the pass data, drafts and elongations and Figure 19 shows a composite computation sheet which lists the various other data that Figure 18 does not contain.

which the power requirements changed with the changes in roll speeds.

Figures 24, 25, 26 and 27 show the log sheets for three blooms rolled for each of the four different mill speeds. These sheets were worked up in detail to determine whether the horsepower seconds per cubic inch displaced were uniform for the different passes at the different speeds. It will be observed that no marked difference occurs for similar speeds and like temperatures. Where a great difference is noted, it will be seen that there was also an appreciable difference in temperatures.

It will be noted that the light load loss for the roller bearing mills is quite constant. Considerable fluctuation occurred in the light load loss in the plain

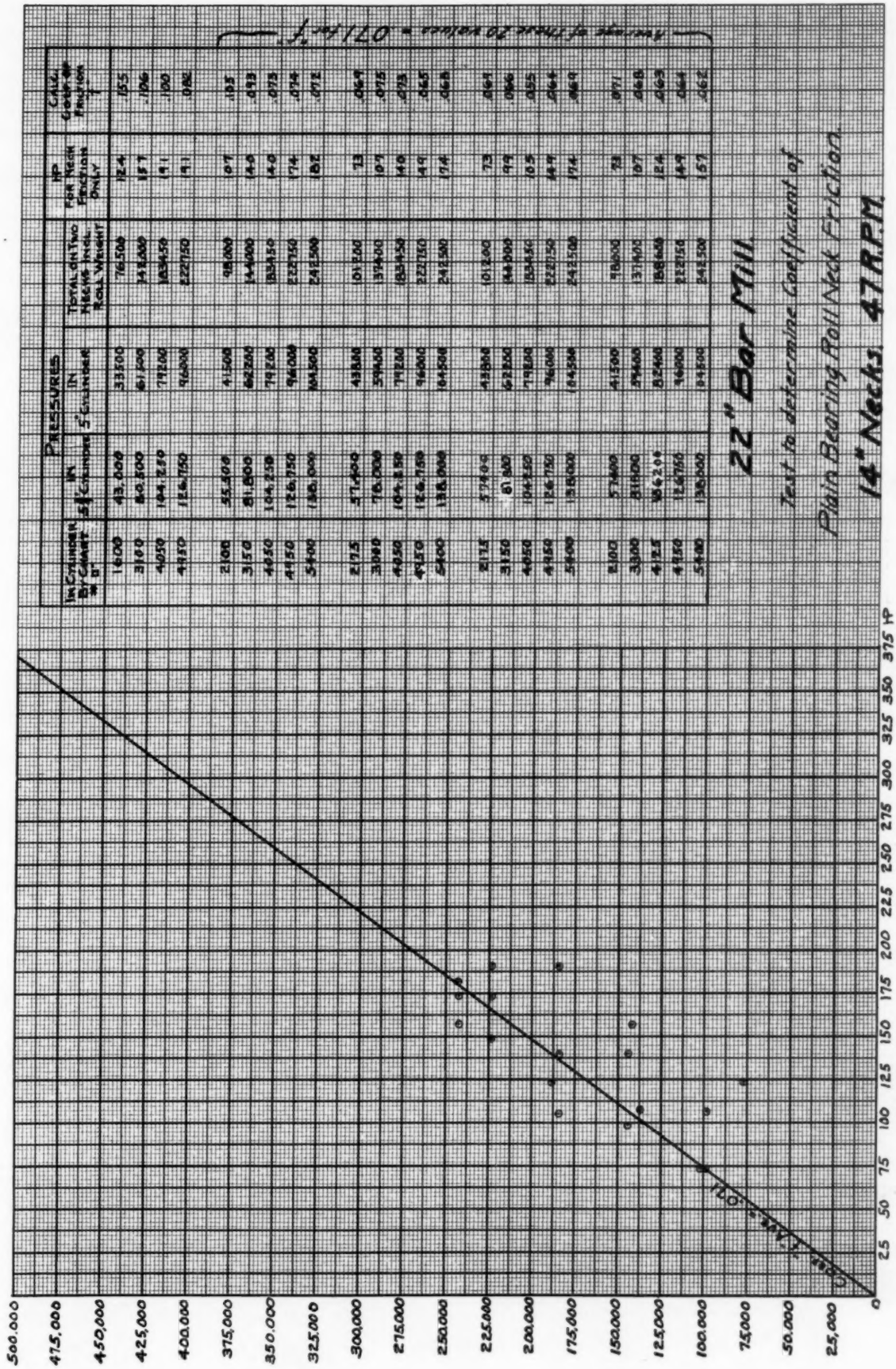

22" Bar Mill.
Test to determine Coefficient of
Plain Bearing Roll Neck Friction.
14" Necks. 47 R.P.M.
Pressures
In Cylinder By Gauge #
In Cylinder Lbs.
In 5" Cylinder
Total on Two Necks Incl. Roll Weight
HP For Neck Friction Only
Coef. of Friction f
f = .07 / 120 = erosion of necks in service
500,000
475,000
450,000
425,000
400,000
375,000
350,000
325,000
300,000
275,000
250,000
225,000
200,000
175,000
150,000
125,000
100,000
75,000
50,000
25,000
0
25 50 75 100 125 150 175 200 225 250 275 300 325 350 375 HP

FIG. 17A.

bearing mills. This no doubt can be traced to the probability that lubrication is not perfect at any time, and that occasionally more grease finds its way to the necks and for a short interval there is less friction, at least until the film is again destroyed.

In arriving at the other losses, the drive and pinion stand were carefully analysed. The tooth losses were calculated on the basis of .0042 for the load losses were taken at 4%, and the roller bearing coefficient of friction. An overall efficiency of 95% each was used for the gear drive and pinions.

The neck friction losses for the plain bearing mills were calculated from the rolling pressures and a coefficient of friction of .071. The neck friction losses in the roller bearing mills were calculated on a basis of .0021 for the coefficient.

The motor losses were assumed at 8% total, that is, since during light load there already was a loss of about 60 horsepower in the motor itself, only the difference between that amount and that actually represented by 8% of the total input while rolling was deducted as additional motor loss.

Having finally established the Net horsepower rates for actual displacements, it merely remained to reduce these to horsepower seconds / cubic inch, which, we thought, if they were quite similar, should indicate that our procedure as to the other losses was correct.

In summarizing the results of the tests on the 28" and 22" mills, we learn that rolling pressures as high as 747,000# were attained in the 28" mill, and that the maximum reached in the 22" mill was 270,000#.

It appears that the coefficient of friction of 14" diameter necks on plain bearings averages about .071 but that with defective lubrication it may be slightly higher.

Checks made to determine the length of lever arm upon which the rolling pressure acts and establishes the torque for the work of actual displacement (in the 22" mills) yielded results that ranged from .52 ad to .60 ad, with an average of .565 ad for the square passes; and from .36 ad to .42 ad, with an average of .396 ad for the diamond passes, ad in each case being the horizontal projected length of contact between roll and steel.

Whether or not the averages will hold true for different sizes of bar mills cannot be said. It appears, however, that the lever arm is considerably shorter than obtains in blooming mills, and that the resultant pressure does not bisect the arc of contact but rather cuts the area of work some where near its center of gravity.

22"-3 High Mill.

Pass Data.

Pass No	Entering Size H × W	Entering Area □"	Delivery Size H × W	Delivery Area □"	Draft □"	Draft %	Elong. This Pass	Elong. Total incl. this Pass
1	9" × 8"	64.81	8" × 8"	60.64	4.17	6.4	1.07	1.07
2	8" × 8"	60.64	7" × 8 1/8"	53.48	7.16	11.8	1.134	1.213
3	8 1/8" × 7"	53.48	7" × 7"	46.16	7.32	13.7	1.157	1.404
4	7" × 7"	46.16	6" × 7 1/8"	39.60	6.56	14.2	1.165	1.638
5	7 1/8" × 6"	39.60	6" × 6 1/8"	35.04	4.56	11.5	1.130	1.851
6	6" × 6 1/8"	35.04	5" × 6 5/16"	29.04	6.00	17.1	1.206	2.232
7	6 5/16" × 5"	29.04	5" × 5 1/4"	24.26	4.78	16.5	1.195	2.672
8	5 1/8" × 5"	24.26	4" × 5 3/8"	19.64	4.62	19.0	1.233	3.306
9	5 3/8" × 4"	19.64	4 3/8" × 4 5/16"	18.75	89	4.5	1.047	3.460
10	4 3/8" × 4 5/16" sq.	18.75	4 13/16" × 5 1/4"	15.81	2.94	11.3	1.184	4.110
11	5 1/4" × 4 13/16"	15.81	4 7/16" × 4 15/16"	13.4	2.41	15.2	1.180	4.840
12	4 15/16" × 4 7/16"	13.40	4" × 4 3/4"	10.77	2.63	19.5	1.245	6.030
13	4 3/4" × 4"	10.77	3 5/8" × 4 3/16"	9.02	1.75	16.2	1.193	7.200
14	4 3/16" × 3 5/8"	9.02	3 1/4" × 3 7/8"	7.28	1.74	19.3	1.238	8.920
15	3 7/8" × 3 1/4"	7.28	3 1/4" × 3 1/2"	7.08	.20	9.7	1.030	9.160

Diamond Passes

FIG. 18.

Mill 22" 1&2
Test No.
Date 4-26-30
Steel 2345
Product 2 11/16" □

Bearings Fl. ✓
Fl. Bg. Neck 14" x 14" lg.
Iron in bearing 189 sq"
Length in bending 7"

R.P.M.	R.P.M.	R.P.M.	R.P.M.
268 Motor.	314 Motor.	365 Motor.	430 Motor.
52 Mills.	61 Mills.	71 Mills.	83.5 Mills.

Pass No.	Radius of roll bottom of pass Ent. R1	Mid. R2	Top R3	Steel in this roll pass H	h	Total Red. Inch.	Mean Prop.	W Width of Steel in pass Ins.	Proj. Arc of Cont. Ins.	Roll Penetration	Equivalent Reduction	Equivalent Diameter	Ave. R.P.M. Rolls	Calculated Compression Rate.	Rolling Pressure K Avg.	Curve Points K	Temp. °F	Calculated Compression Rate.	Rolling Pressure K Ave.	Calculated Compression Rate.	Rolling Pressure K Ave.	Calculated Compression Rate.	Rolling Pressure K Ave.
1	7 3/32	7 3/32		9	8	1	2 3/32	8	21.8	1/2	1	9	52	1.65	237500	11000	2093	1.94	256645	2.25	244534	2.63	240130
2		7 3/32	7 3/32	8	7	1	2 3/32	8 1/4	21.9	1/2	1	8	"	1.86	184000	8400	2090	2.18	195800	2.64	167408	2.98	181120
3	7 3/32	6 7/32		8 1/4	7	1 1/4	2 3/32	7	20.8	9/16	1 1/4	8 1/4	"	2.00	204000	9820	2063	2.35	217290	2.72	210322	3.20	205520
4		6 7/32	6 7/32	7	6	1	2 3/32	7 1/8	20.0	1/2	1	7	"	2.21	202000	10100	2033	2.60	213745	3.02	200409	3.56	200600
5	6 7/32	6 7/32		7 1/8	6	1 1/4	3 1/16	6 1/8	18.6	9/16	1 1/8	7 1/8	"	2.34	214000	11500	2034	2.76	222386	3.20	213889	3.77	221350
6		6 7/32	6 31/32	6	5	1	2 3/16	6 1/8	18.3	1/2	1	6	"	2.68	208500	11600	1972	3.14	214800	3.65	209412	4.29	222780
7	6 31/32	6 7/32		6 1/8	5	1 1/8	3 1/16	5 1/8	17.3	31/32	1 1/8	6 1/16	"	2.95	229000	13210	1983	3.47	242379	4.02	233485	4.74	239370
8		9 7/32	9 7/32	5 1/8	4	1 1/4	3 1/16	5 1/4	17.35	9/16	1 1/8	5 1/8	"	3.39	180730	10410	1960	3.98	216532	4.63	219215	5.45	189600
9	9 7/32	9 7/32		5 1/8	4 3/8	1	3	4 3/8	12.47	1/2	1	5 1/16	"	3.05	133200	10470	1949	3.58	133241	4.16	130342	4.90	126100
10		8 7/8	8 7/16	5 3/8	4 1/8	1 1/4	2.96	5.63	11.07	15/32	15/16	5 3/8	"	2.75	147000	13300	1917	3.23	149215	3.78	154293	4.42	147430
11	9	9 1/16		5 1/4	4 1/8	1 1/8	3 1/16	4 5/8	10.11	7/32	1 1/8	5 1/4	"	3.05	180000	17800	1840	3.58	182398	4.16	175426	4.90	173620
12		9 7/32	9 7/32	4 5/8	4	5/8	2 1/16	4 3/8	8.8	15/32	7/16	4 7/16	"	3.25	196600	22350	1817	3.81	200104	4.44	204624	5.23	198750
13	9 7/32	9 9/32		4 3/8	3 3/8	1	3 1/4	4 3/8	8.07	9/16	1 1/8	4 3/4	"	3.74	182560	22620	1829	4.38	183760	5.07	185428	6.00	179180
14		9 11/32	9 9/32	4 3/8	3 1/8	1 1/4	3	3 3/8	7.45	17/32	7/16	4 3/16	"	3.91	191160	25700	1835	4.68	191357	5.34	199205	6.30	186420
15	9 7/32	9 7/32		3 3/8	3 1/8	1/4	2 1/16	3 3/8	4.62	7/32	7/16	3 7/8	"	2.90	113630	22400	1751	3.41	109294	3.96	112026	4.67	107600

#1 Stand

#2 Stand

FIG. 19.

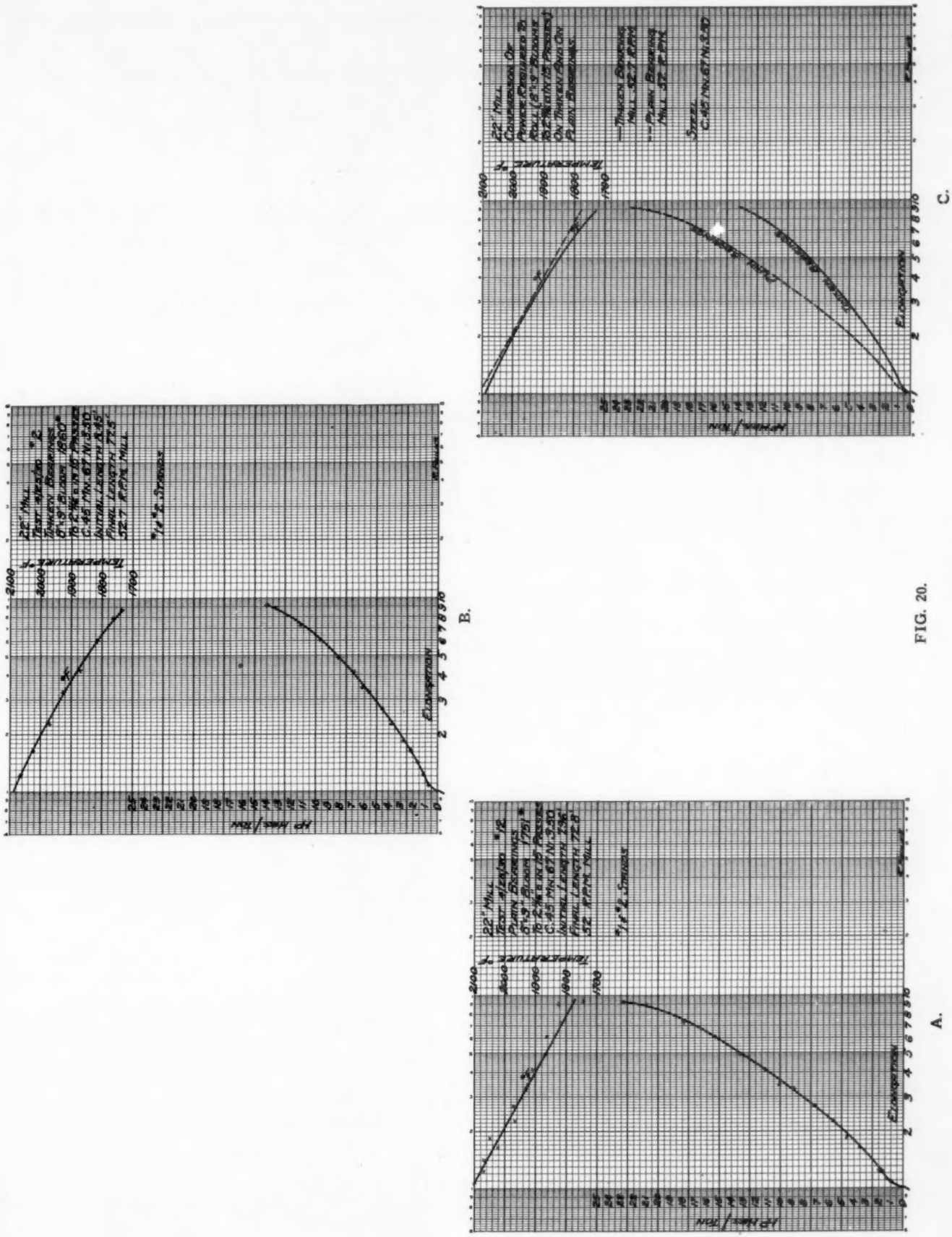


FIG. 20.

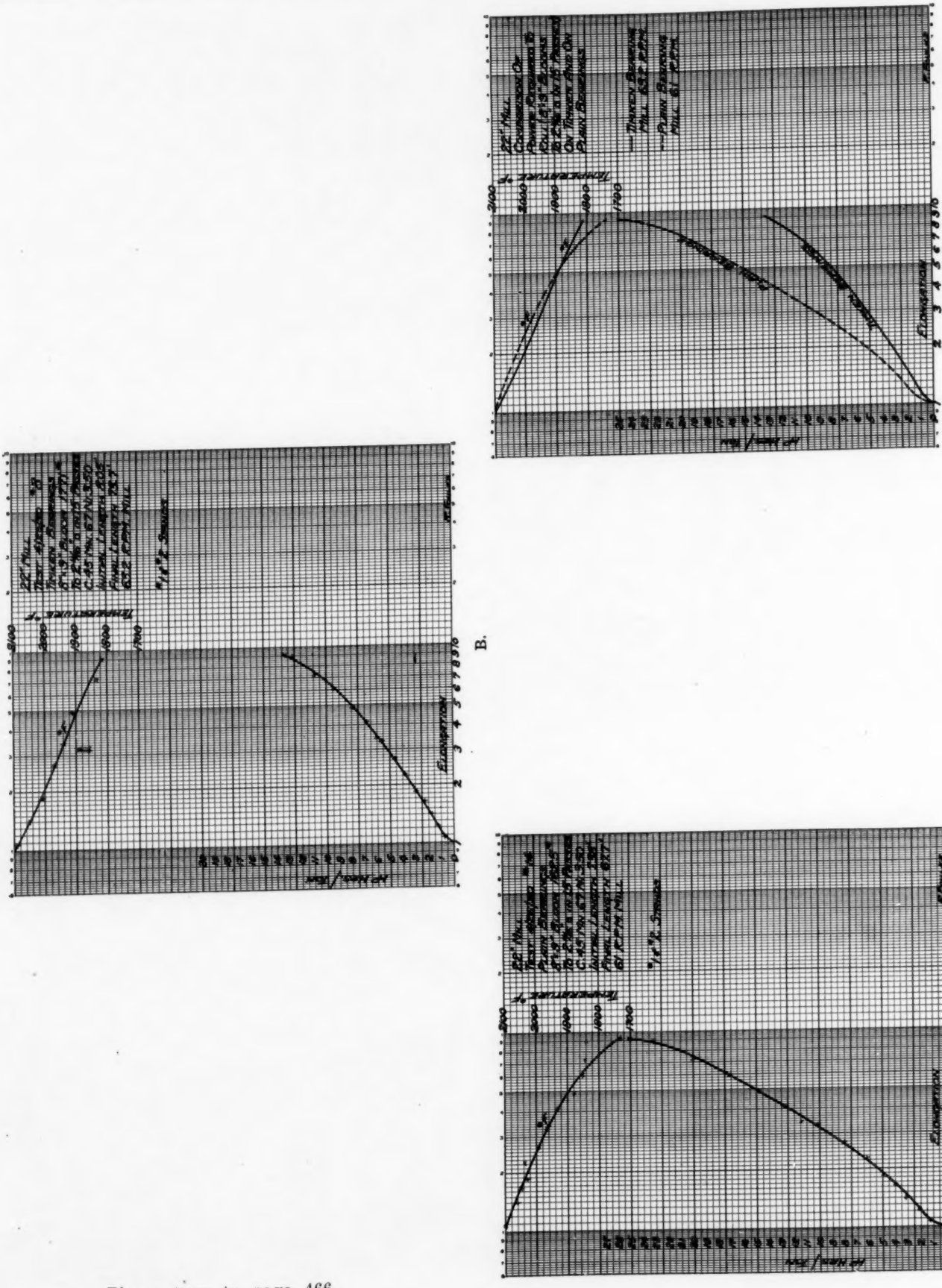


FIG. 21.

Please turn to page 466

Locomotives with Internal Combustion Engines for Steel Mill Transportation

By A. H. Candee*

Until very recently, the steam locomotive has held undisputed sway in steel mill transportation. This type of locomotive has been a reliable tool for the movement of materials into and out of the plant, and between the various parts of the mill. Its operation has been well understood and consequently it has performed with a reasonable degree of reliability, but the chief objection has been the cost of operation and maintenance. To keep abreast of the economic improvements in other parts of the mill, it becomes increasingly important to reduce the cost of transportation.

The fact that there have been numerous studies and attempts to electrify the transportation systems of steel mills, indicates that the economic urge has been with us for some time. The trends toward electrification of the mills themselves, and the benefits in increased production at lower costs, resulting therefrom, were the natural reason for attempting to extend the use of electricity to all of the power requirements of the plant. Nearly all of such transportation electrifications, however, have failed to fulfill the complete requirements of a steel mill transportation system, because it is not permissible to place trolley wires over the tracks within some of the buildings or where cranes are used. On the other hand, third rails are dangerous and cannot be used.

To be commercially successful as a motive power unit in steel mill work, a locomotive must carry its own source of power. As an alternate to the steam locomotive, a storage battery unit meets this requirement, but the time necessary for recharging of the battery imposes a severe handicap where continuous transportation is necessary. Were such locomotives to be used throughout in place of the steam locomotives, it would be necessary to provide a greater number than of the steam locomotives replaced, which increases the investment and in the end proves to be no more economical than steam operation.

In 1924, a new type of self-propelled locomotive appeared in steam railroad switching service. This was the oil electric locomotive—so-called because the prime mover is a Diesel (or "oil") engine, and the transmission from the engine to the wheels is accomplished by the use of electrical apparatus. Its economies were apparent at once, its overall thermal efficiency being approximately 26% where the steam locomotive thermal efficiency averages 2% in switching service. Its use has spread not only in railroad switching, but to industrial plant switching and steel mill transportation. While this type of motive power is still comparatively new, it has fully demonstrated its reliability and suitability for all classes of switching service, and its field is extending to embrace the complete railroad motive power requirements. The tremendous amount of money required to develop and prove the larger sizes of engines which will be used in freight and passenger locomotives, naturally means that the application of the oil engine to such services will take time.

* General Engineer, Westinghouse Electric & Manufacturing Company, East Pittsburgh, Pa.

The Prime Mover

Before discussing the application of the oil electric locomotive to industrial switching, it may be well to give consideration to the prime mover itself, and its adaption to railroad motive power purposes. While most of you have undoubtedly become familiar with some of the units which are in operation, a discussion of the fundamentals of engine design may well be worth while. It should be understood that the ordinary Diesel engine is not applicable to a rail vehicle on account of the size and weight.

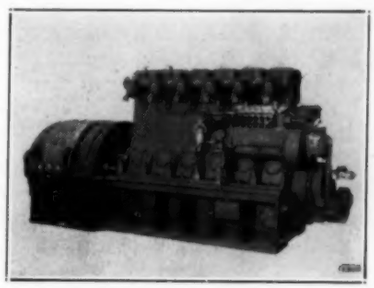


FIG. 1—300 H.P. Oil Engine.

The automobile has educated the American public as to the operation of a 4-cycle internal combustion engine. The 4-cycle Diesel engine such as is used in locomotives is very similar in its operation to that of the gasoline engine, with the exception of the method of introducing the fuel to the cylinder and its ignition. If we follow the cycle through the explosion stroke, the exhaust stroke, the suction and compression strokes, we find that the gases resulting from the burning of the fuel expand in exactly the same way as in a gasoline engine. However, on account of higher compression pressures, these gases are exhausted at a lower pressure than in the gasoline engine. The exhaust stroke forces the burned gases out in exactly the same way as in a gasoline engine, but due to the fact that the space between the piston and the cylinder head at the top of the stroke is smaller than in the gasoline engine, a greater percentage of the gases are forced out in the exhaust. The difference in operation commences with the suction stroke, for the Diesel engine draws in a charge of air only, while the gasoline engine draws in a fuel mixture. On the compression stroke, both engines compress the charge in the cylinder, but in the case of the Diesel engine, this pressure is very much higher than that of the gasoline engine, so that the compressed air reaches a tempera-

ture sufficiently high to ignite a charge of fuel which may be sprayed into the cylinder. Near the top of the compression stroke, such spraying occurs, the fuel being driven into the hot air through fine holes in the atomizer, and the combustion begins as the spray enters the cylinder. The injection is timed, just as the gasoline engine spark is timed.

Until the development of the high-speed Diesel engine for railway purposes, it had been customary to inject the fuel into the cylinder by means of highly compressed air. As noted, the compression and explosion pressures in the cylinder of a Diesel engine are high, and the injection air must, therefore, be compressed to at least 1000 lbs. per square inch in order to properly inject the fuel charge, and considerable difficulty results from the use of compressors for preparing this injection air. The difficulties and dangers of compressing, storing, and distributing 1000 lbs. air on a locomotive where some vibration is always present, may be readily recognized, and pipe failures may be extremely dangerous to the operators. To eliminate these dangers and to provide a simple and reliable method of injecting the fuel, nearly all of the builders of high speed engines for locomotive purposes have resorted to mechanical pressures for forcing the fuel through the injection nozzles. While such mechanical pressures are usually above 4000 lbs. per square inch, they may be easily obtained by plunger pumps, and dangers due to pipe fractures are negligible. It is customary to differentiate between the air injection engines and the mechanical (or solid) injection engine by calling the air injection the "Diesel engine," and the other the "oil engine."

Oil engines, as used for stationary and marine purposes, have been of extremely low speed, which, in turn, necessitated large cylinders, heavy reciprocating parts, and massive construction throughout. Built for continuous and protracted duty, where space had not to be conserved as much as in a locomotive, cross heads were used which, of course, added to the weight and size. Such engines, however, are extremely reliable and have an astonishingly long life. To adapt such an engine to rail purposes was, of course, impractical, and even though marine engines are somewhat smaller and lighter, and high speed than stationary engines, they were considerably too large and heavy to be used. It was, therefore, necessary to push up the speeds and lighten the parts to a minimum consistent with reasonable life before locomotive requirements could be met. While gasoline engines suitable for rail transportation work were available, experience gained thereby could serve as a partial guide only in this new and unknown field of light weight oil engines.

In order to visualize what is required in engine sizes, it may be pointed out that while each railroad or industrial plant has its own limits in height and width of locomotive cab, average clearances will limit the cab width to 10′6″, and the overall height above the rails to not more than 15 ft. These dimensions then necessitate the building of engines of such dimensions that they may be installed within a cab having those outside dimensions with space left for the proper maintenance operations. As the height required for the locomotive underframing and trucks must be deducted from the overall height, and since these cannot be changed readily, it will be found that the engine must not be over 7 ft. in height in order to be installed in a cab, and preferably should be less than this to permit the removal of cylinder heads and pistons without removing the locomotive roof. As engines are usually narrow, width limitations do not seriously inconvenience the application, except as it affects the space available along the sides of the locomotive for stowing tanks and auxiliary equipment. The length of a locomotive is not usually a limiting factor, but an engine cannot be built too long because of difficulties encountered in the operation of long crank shafts, which are subject to dangerous critical torsional vibrations.

There is but one general engine type suitable for locomotive purposes—that is, the high-speed engine. Cross heads may not be used because of height restrictions. The first oil engines built for car or locomotive purposes, therefore, operated at 550 RPM. where few stationary or marine Diesels operated at above half that speed. Designs have now advanced to the point where 900 RPM. engines are being manufactured, and two comparatively large engines of 1330 HP. each are operating at 800 RPM. in a Canadian National passenger locomotive of 334 tons.

There are a number of features in connection with the design of high speed oil engines, which may be of considerable interest. The amount of oil which is sprayed into each cylinder of a 400 HP., 900 RPM. engine at the beginning of an explosion stroke is about the amount of oil which may be held on the surface of a cent. This minute quantity must be accurately metered, timed and sprayed into the cylinder in a finely divided cloud to permit of rapid combustion, and the time permitted for this operation is less than 1/1000 of a second. This operation requires very close machining of fuel pumps and injection nozzles, but with present day practices, has been successfully accomplished.

The weight of pistons and connecting rods is of prime importance where relatively high reciprocating speeds are employed. High grade materials are employed to keep down the weights, and in fact, high grade materials are used throughout the engines for the same purpose.

Torsional critical speeds must be avoided. As it is practically impossible to build any reciprocating engine having a range of speed such as are employed in locomotive Diesels (300 to 900) without encountering torsional critical points, most engines are provided with vibration dampers. Such a damper neutralizes the vibrations and does not allow them to build up to a point where the crank shaft material is stressed excessively.

Engines must be governed not only with an overspeed governor, but also where the engine is idled such as in locomotive engines, the idling speed must also be governed. This is not necessarily true of a gasoline engine, because there is an element of stability in a gasoline engine due to manifold depression which is not present in an oil engine. With the engine governed at full speed and at idling speed, it is a simple matter to arrange the governor to control the engine speed at any intermediate point desired.

Electrical Equipment

It is not practical to transmit the power from an internal combustion engine in a locomotive to the wheels of such a locomotive by mechanical means. It has been tried with gasoline engined equipments, and except in the very smallest sizes, has given rise to considerable maintenance cost. Hydraulic transmissions have been tried, but the efficiencies are extremely low, and the system as a whole has not proven reliable. Electrical transmission, however, not only embodies reliability, but provides a very flexible medium of transmitting the energy to the rails, and locomotives equipped with this type of transmission can handle heavier trains than with mechanical transmission, even though efficiency of the mechanical transmission is said to be somewhat higher than that of the electrical system.

The electrical equipment used for transmission consists of two fundamental items—the generator connected to the engine, and the motors geared to the axles of the unit. It is customary to use one motor for each axle, all motors being fed from the single generator attached to the engine. Auxiliary equipment, of course, must be provided to care for reversing of the propulsion motors, proper flow of power from the generator to the motor, field excitation and operation of fans and similar devices. It is not necessary to go into the details of this equipment, but it may suffice to say that the electrical apparatus is simple to understand and easily maintained.

The control of the flow of electrical power has recently advanced to a point where it now loads the engine very effectively at all locomotive speeds. It is a well known fact that engine condition will vary from time to time, due to atmospheric conditions, carbonization, leakage in valves, and for other reasons of a similar nature, and the newer systems of control account for these changes in a very simple manner.

Internal Combustion Engined Locomotive

The assembly of the component parts of a locomotive involves a number of details which are of extreme importance. With an engine available and the electrical transmission system of suitable size for the engine, the next problem is to arrange for running gear and a cab to house the equipment with auxiliary details such as radiators, fuel tanks, sand boxes, water tanks, equipment cabinets, operator's compartment, and the numerous details such as headlights and bells that are required. In laying out a locomotive, it is necessary to consider the fundamental which is, that for light switching duty the locomotive should have at least 5 HP. per ton of weight on driving wheels, and preferably 6 HP. per ton. For heavier duty, this ratio should rise to 7 or 8 HP. per ton. For road freight and passenger work, it is preferable that this be in excess of 10 HP. per ton. These figures are based on experience as those being required for expeditious handling of trains. Thus, with a 400 HP. engine for the lighter switching duty, the locomotive should weigh in the neighborhood of 70 tons, and for an 800 HP. locomotive, should preferably have a net weight of approximately 110 tons. It is not always possible to get the weights as low as those believed to be most desirable, but the design should be laid out with an ultimate weight in view. At the outset, this necessitates low power plant weight, as every pound added to this unit involves additional increase in strength and weight of the locomotive structure, thus pyramiding weights.

In single power plant locomotives, the engine is usually placed on the center line of the locomotive, and rests solidly on the locomotive frame. The vibrations which are transmitted from the engine to the cab structure are so small that the use of cushions or springs has not been found necessary. Pipe connections from the engine to the cab structure, however, must have some flexibility to allow for slight relative movement of the engine, due to these small vibrations, temperature changes, or weaving of the cab itself.

The auxiliary apparatus is grouped around the sides and the ends of the locomotive in such a manner as to permit full accessibility for power plant and auxiliary equipment maintenance. In order to insure that the radiators will not freeze in cold weather, they are located on the roof, out of the way and are arranged to drain automatically into a storage tank inside of the locomotive cab. It is essential that such a storage tank be located high in the locomotive in order to insure that the cylinder heads are not drained. Radiator ventilating motors are necessary in slow speed switching service as it has been found that natural ventilation cannot be relied upon. These same remarks apply to lubricating oil radiation systems where used, and it may be pointed out that nearly all large oil engines and gas engines carry off sufficient heat in the lubricating oil to require cooling of this oil. With the water and lubricating oil draining to the inside of the cab, it is necessary to supply a small coal heater within the cab to keep the cab and engine warm enough to prevent freezing where ambient winter temperatures below freezing are encountered. Such a heater is usually of the hot water type, and is connected to circulate warm water through the engine jackets to provide for easy starting of the engine.

Sand boxes are usually placed for convenient filling from the outside of the locomotive to reduce the possibility of getting this fine abrasive dust inside of the engine. It is customary to locate the batteries along the sides of the locomotive on the cab floor, and electrical control cabinets for mounting the panels are placed along the sides or the ends of the locomotive out of the way and yet accessible for inspection and repair.

In the earlier locomotives, the engine was started by means of compressed air. Nearly all recent applications, however, employ the use of electric starting, the main generator being used as a motor and receiving starting power from a storage battery. The starting of an oil engine is somewhat different from a gasoline engine. Because of the high compression, it requires more power to turn the engine over initially, and on account of the fact that the engine will not "fire" until the proper compression temperatures are reached, it is necessary to spin the engine at a relatively high speed to attain these temperatures.

The operator's compartment is separated from the main engine room by a bulkhead which shields

the operator from the engine noises and heat. The most desirable arrangement, especially in industrial switching operations is that which will permit the use of a single man on the locomotive, and in order to permit him to receive signals from the ground

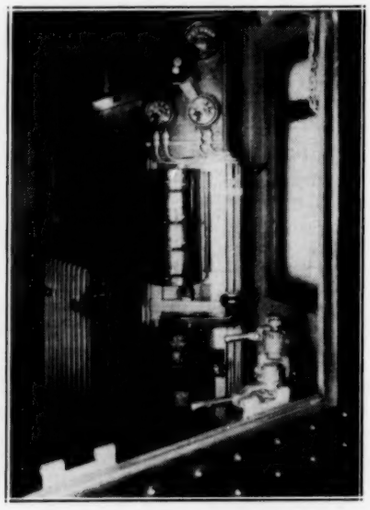


FIG. 2—Oil Locomotive Control Station.

crew on either side of the train, there must be an operating station on each side of the locomotive so arranged that he may conveniently step from one side to the other, having full control of the power and braking at all times. In addition, it is desirable that he have an unobstructed view from either side of the locomotive, especially during wet or cold weather when it is undesirable for him to put his head out of the window. This has been accomplished by the use of a "visibility cab" as will be shown in the accompanying slide.

Locomotive Speed-Tractive Effort Characteristic

The speed-tractive effort characteristics of an oil electric locomotive are different from those of a steam locomotive. In the case of a steam locomotive, the maximum tractive effort is a definite quantity as fixed by steam pressure, area of pistons, length of stroke, wheel diameter and crank angle. As the locomotive speed increases, the horsepower increases to a point where the maximum tractive effort may not be sustained, after which the horsepower rises at a somewhat lower rate than the increase in locomotive speed. In the case of the oil electric locomotive, however, the maximum tractive effort is fixed only by the ability of the generator to force current through the motors, and this develops a tractive effort far in excess of that required to slip the wheels. Thus, the slipping point of the wheels is the limit and it may be noted that with electric transmission, this maximum tractive effort is continuous, and does not fluctuate as in the case of the steam locomotive.

With a given maximum engine capacity, or maximum continuous horsepower available, there is a definite limit to the locomotive speed which may be attained at any tractive effort. If you will plot the speed-tractive effort curve with a definite limited horsepower, you will find that the resultant curve is hyperbolic in shape. However, most of the work in switching service is accomplished within the speed range where the tractive effort exceeds that of the steam locomotive.

The oil electric locomotive will perform the equivalent of steam service with a much less installed capacity. This is primarily due to the ease of reversing and control of power, as well as to the improvement in tractive effort at the lower speeds. Nearly all switching work is within the range of speeds at which the steam locomotive cannot develop its maximum power, whereas the full Diesel horsepower may be utilized at any locomotive speed.

The Oil Electric Locomotive In Steel Mills

The production of steel is a continuous process. Such continuous process naturally requires that materials be moved with continuous regularity in order to avoid interruptions of production. Delays cannot be tolerated and the rail motive power unit must, therefore, be reliable. Transportation cost is of secondary importance to continuity of operation.

All classes of service are involved in mill transportation, from the slow speed "spotting" work at loading platforms, to the heavy high-speed classification work of incoming and outbound shipments. Hot metal and slag must be moved without delay, as well as other furnace material. Trestles are often encountered which require heavy and sustained tractive efforts in pushing cars up. The handling of ingot buggies involves unusual rigidity in locomotive structure as the draft gear does not embody flexibility. While a limited amount of power may be installed for the light switching movements, the classification and transfer service involved in handling inbound and outbound traffic requires heavy locomotives with plenty of power for rapid work.

It is the desire to reduce transportation expense that makes the oil electric locomotive so attractive As stated before, electrification where practicable, accomplishes this purpose, and such partial electrifications as have been installed, have given a very

FIG. 3—70-Ton Locomotive.

good account of themselves, both from a reliability standpoint, and from a reduction in operating expenses. The oil electric locomotive, however, not only reduces operating expenses, but offers a degree of reliability in a self-contained unit which recommends it strongly for steel mill purposes. The application of oil electric locomotives to any specific mill should only be made after the conditions are thoroughly studied. It is often possible to re-arrange the schedule of operations in such a way as to reduce the number of oil electric locomotives required

to replace the steam locomotives. In some cases, a slight rearrangement of tracks may effect a similar reduction in expenses. Past operation of steam locomotives has given the operating force sufficient background to permit the selection of new steam motive power equipment without making close analytical studies, but with the new form of motive power having slightly different speed-tractive effort characteristics, sufficient consideration must be given to the application to insure the purchase of the proper weight and horsepower to handle the service and allow for natural expansion of plant capacity.

The savings which may be accomplished by the use of oil electric motive power vary widely with the conditions encountered. In our own plant, which involves industrial switching only, we have been able to show a very startling saving by employing the oil locomotive continuously, where the steam locomotives are operated 16 hours per day. By doing this, it is possible to completely discard one steam locomotive. Without the presentation of a mass of individual data, it may be stated that the average savings in steel mill service are effected as follows:

Fuel expense reduced to 1/5th of coal.
Water expense reduced to zero.
Fireman eliminated.
Repair expense reduced to ½.
Engine house expense approximately 5/8 of similar steam expense.

The only items which are increased are lubrication and capital charge, each being approximately double that of steam operation. It must be pointed out that the oil electric locomotive is considerably higher in first cost than a steam unit for the same service, but in spite of the higher first cost and lubricating oil expense, the operating cost of the oil electric average 50% of the steam operating cost.

It may not be possible to realize the full benefits of the oil electric locomotive without making a complete substitution of the oil electrics for the steamers, although each oil electric applied results in a reduced operating expense. With the steam locomotive eliminated, such attendant facilities as are inherent to their operation may be entirely eliminated, such items being coal chutes, ash pits, and water tanks.

FIG. 4—55-Ton Oil Electric Locomotive.

You may note that no mention has been made of the gasoline electric locomotive. It has been found by actual applications as well as by calculation that such locomotives operate well in industrial service, but their fuel cost is high. This is the chief reason for the preference given to the oil electric units, which burns a cheaper fuel and whose thermal efficiency is higher. Where the hours of service are low, however, the gasoline engined locomotive sometimes shows economies over the oil engined type, due to its low initial cost.

Additional Advantages of Oil Electric Locomotive

Consideration has been given so far only to the economic advantages of the oil electric locomotive. There are a number of other advantages of sufficient importance to be given careful consideration. Among these are:

(1) In entering buildings, the locomotive exhaust is much less objectionable than that of a steam locomotive, and the fumes do not contain carbon monoxide.

(2) Absolute control of locomotive movement at all times improves the handling of hot metal and ingot buggies, and reduces the damage to cars and lading.

(3) The safety to the operator and ground crew is improved by the increased visibility features. The possibility of collision is reduced.

(4) Two or more locomotives may be operated by a single man in multiple as the occasion arises. This adds a flexibility to the motive power unit which is not inherent with the steam locomotive.

(5) The oil electric locomotive is clean and comfortable. Reversing and power control require very little manual effort, which leaves the operator in better physical condition at the end of his trick than the steam locomotive operator.

(6) Fuel oil is not readily ignited, and there are no large volumes of stored gases. This reduces the operating hazards to a minimum.

(7) Stand-by attendance is very materially reduced.

(8) In case of derailment, the locomotive is much more easily rerailed than with steam motive power.

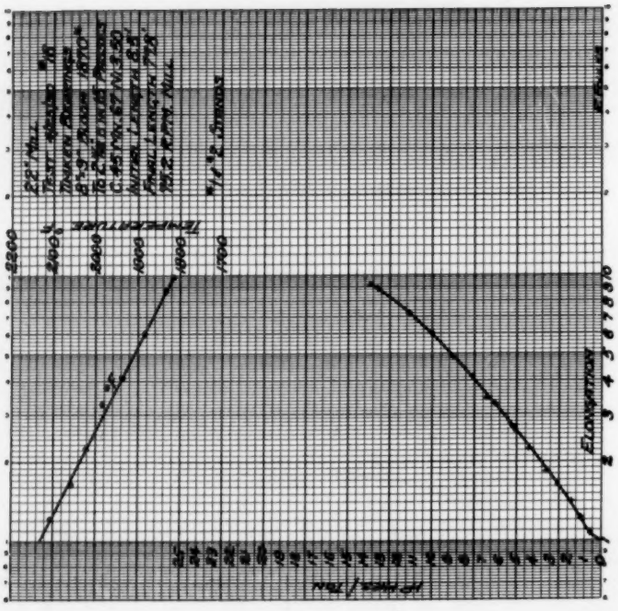
Combination Locomotives

A modified oil electric locomotive has recently appeared on the horizon. This is the combination oil electric-storage battery locomotive. The addition of a storage battery to the oil electric locomotive will permit of large power drafts for short times with the use of a small oil engine. The economic importance of this combination unit has not been definitely approved, nor has it progressed to a point where its legitimate field is definitely outlined. Only detail studies of a given plant will determine whether such a unit may be applied.

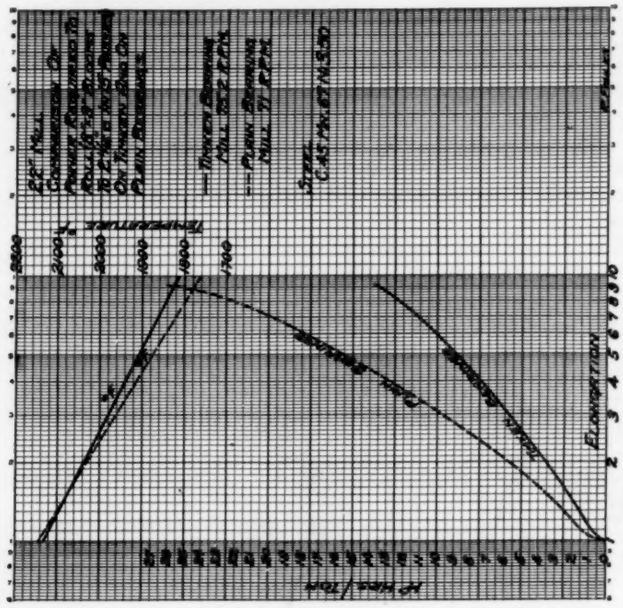
Conclusion

Six years of development of the oil electric locomotive have shown the economic importance of this type of motive power in switching service. There is a great deal of development confronting the designer, but improvements may be made only by cooperation of the users and the manufacturers of this type of vehicle. The steam locomotive has had 100 years of development, and is still being improved. The important consideration is that, in spite of the fact that this locomotive is still in its infancy, it has proven reliable and much more economical than the steam locomotive, and may be purchased by steel mills with the full assurance that it is an operating unit, and not merely a dream.

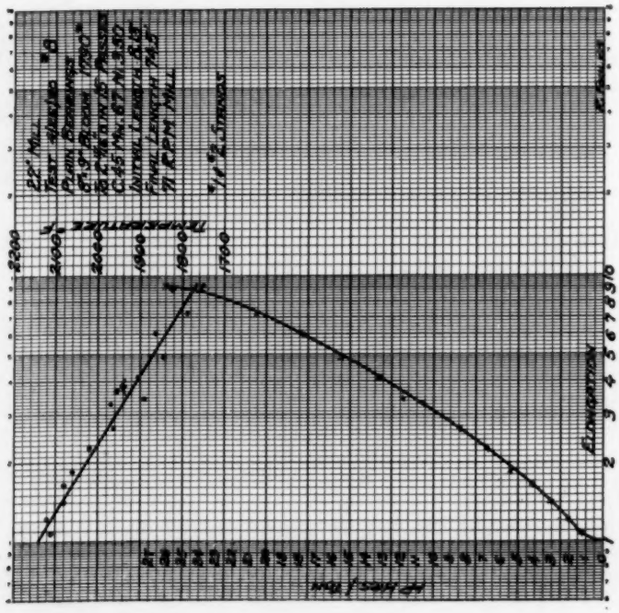
(Continued from Page 460)



B.

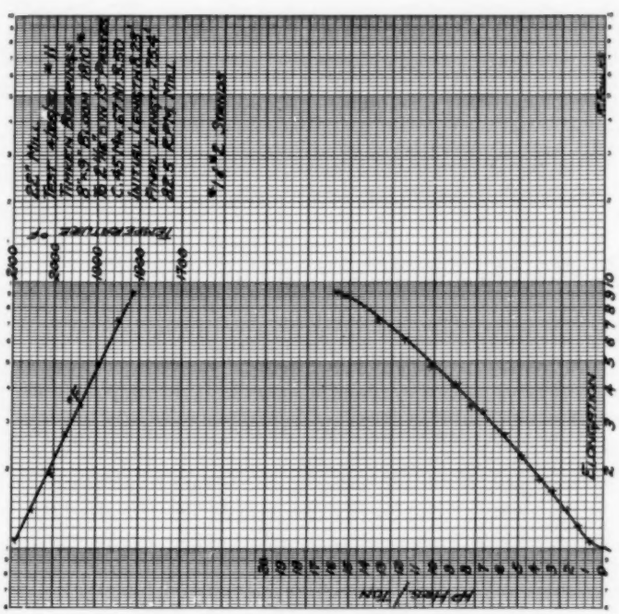


C.

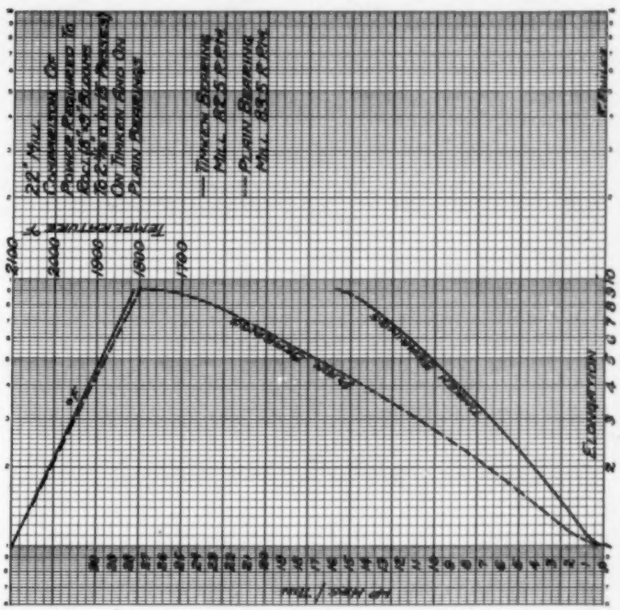


A.

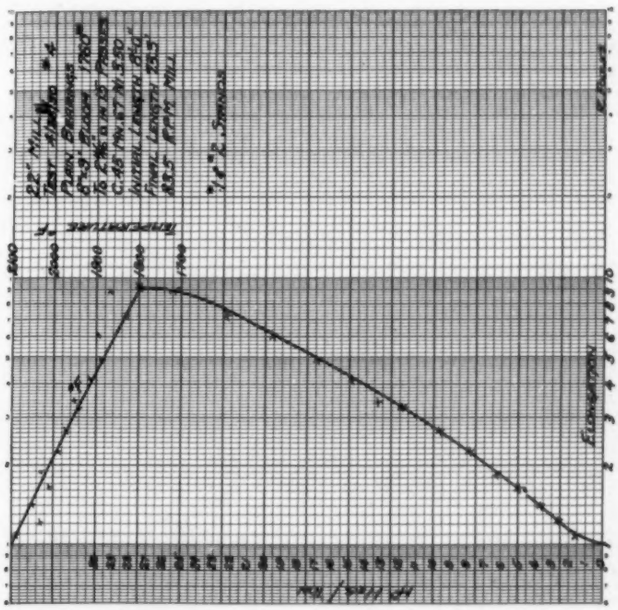
FIG. 22.



B.



C.



A.

FIG. 23.

Returning for a moment to the compression rate formula, if we write it $\frac{.105\,N\sqrt{R}\sqrt{r}}{H}$ it seems to substantiate the theories advanced by some steel mill engineers.

For instance, since the Rate fixes the resistance the steel offers to deformation, the formula shows that if the temperature remains constant, the resistance varies directly with the speed N. It also bears out the opinion of some that the pressure increases directly with the square root of the roll radius R. That the pressure is also fixed by the reduction r is well known, but as the length of contact is established by both the roll radius and the reduction, it appears that the resistance also varies directly with the square root of the reduction.

Finally the position of the height H in the formula indicates that the resistance varies inversely with the height before the pass. Since the density of the steel increases with each pass it must offer more resistance to deformation as it proceeds through the mills. As it requires less pressure to compress hay into a bale than it does to compress the bale itself; the position of the height H in the formula is correct. It shows that as the height grows smaller, the pressure increases because a decrease in the height produces an increase in the Rate.

We regret that time did not permit of analysing the tests we conducted on our Merchant and Tube Mills. The results of those tests must, therefore, be incorporated in another report which can be printed in the "Iron and Steel Engineer," or published separately at a later date.

We gratefully acknowledge the service rendered by the General Electric Company's engineers who undertook to accumulate the electrical data that made this report possible. Theirs was the greater part of the task we took upon ourselves when we set out to determine the power requirements for our mills. It is hoped that what they have enabled us to report will lend assurance that the savings to be derived from the use of anti-friction bearings in steel mills need not be questioned.

INSPECTION TRIP

auspices

ASSOCIATION OF IRON & STEEL ELECTRICAL ENGINEERS

WROUGHT IRON PLANT

A. M. BYERS COMPANY — AMBRIDGE, PA.

The A. M. Byers Company has developed a process for wrought iron manufacture which is of interest to all of the executives of the Iron and Steel Industry.

Pig iron is melted continuously in cupolas. This molten metal is blown in a Bessemer converter to refined iron conforming to the base metal characteristic of wrought iron. The blowing time is approximately ten minutes for the ten ton heat, and the converter will produce the refined metal in a steady supply on a fifteen minute cycle.

Next follows the key operation of the process, that of disintegration and slag incorporation. It is carried out in a set of unlined cups or thimbles, resting upon cars which may be moved to the several stations representing stages of the process. The cups are rectangular, about 6 feet square and 6 feet deep. One or more is supplied with about 4 feet depth of slag of wrought iron characteristics, melted in a tilting open hearth furnace. Into each cup of slag, three tons of the refined metal is poured in a steady stream, the approximate time being three minutes. Considerable boiling and gas evolution will be noted in the cup, but there is no violence in the reactions. Immediately upon completion of the pour, and quieting of the reactions, the cup is picked up by a crane, and the large surplus of slag is decanted into an adjoining empty thimble, and is available for the following heat of metal, after additions of such make-up slag as may be needed from time to time.

The decanted cup contains a solidified, spongy mass of metal, intermingled with liquid slag, conforming in all respects and surpassing in many, the product of the best hand puddling practice. This "ball" is transferred to a powerful press; and being at a welding heat, is compacted to a solid, rectangular bloom about 18″x22″x6 ft.; accompanied by proper ejection of surplus slag during the squeezing operation. The bloom is immediately rolled to appropriate billet sizes on a large electrically driven reversing blooming mill.

The A. M. Byers Plant at Ambridge, Pa., is modern in every respect and represents the combined talent of steel mill engineering in the United States.

The date of the inspection trip is Thursday, October 23, 1930. You are cordially invited to attend.

Power Tests 22" 3 High Mills.

Kind of ba

R.P.M. of Mill:- 52.

Bloom No. 11
Length 8.06' Weight 1772 Volume 6268 c.i.

Pass No.	Temp °F	Total HPsec per pass.	Time of pass Sec	HPrate per pass	LL and Drive Losses HP	Calc. Neck Fricf HP.	Net Rolling HP	Net HPsec.	Volume Displ Cu. In	HPsec Cu in
1	2090					229300 376			403	
2	2110	2328	2.8	831	126 74	181300 148	483	1350	741	1.82
3	2070	2579	2.9	889		203000 333			858	
4	2040	2799	3.2	875	126 82	190000 156	511	1635	891	1.84
5	2049	3271	3.7	884		206800 338			723	
6	1987	3680	4.3	856	126 78	198300 160	492	2110	1074	1.97
7	2005	4435	4.8	924		214500 352			1031	
8	1987	5284	5.7	927	126 90	184400 151	560	3190	1191	2.68
9	1972	3806	6.6	577		125800 206			285	
10	1941	3900	7.3	534	126 39	140400 115	254	1855	987	1.88
11	1890	5505	8.4	655		173700 285			955	
12	1905	6983	9.6	727	126 58	187300 154	389	3740	1236	3.02
13	1842	7644	11.9	642		175200 287			1021	
14	1853	8870	14.0	634	126 49	191400 157	302	4230	1214	3.48
15	1784	5363	16.3	329		110300 181			172	

Bloom No. 12
Length 7.96' Weight 1751 Volume 6191 c.i.

Pass No	Temp °F	Total HPsec per pass	Time of Pass Sec	HPrate per pass	LL and Drive Losses HP	Calc Neck Fricf HP	Net Rolling HP	Net HPsec	Volume Displ Cu In.	HPsec Cu in
1	2100					262300 430			398	
2	2070					192300 157			732	
3	2070	2516	2.8	899		210700 346			848	
4	2020	3146	3.4	925	126 90	202800 166	543	1845	880	2.1
5	2049	3381	3.8	890		215200 352			714	
6	1965	3460	4.2	824	126 73	204000 168	457	1915	1061	1.81
7	1972	4718	4.9	963		229200 376			1019	
8	1929	5347	5.5	972	126 98	184400 151	597	3280	1177	2.79
9	1926	3853	6.4	602		136900 225			281	
10	1905	3617	7.0	517	126 37	153800 126	228	1595	974	1.64
11	1866	5976	8.0	747		187900 308			945	
12	1866	6763	9.6	704	126 56	202400 166	356	3420	1217	2.81
13	1817	8336	11.8	706		188700 310			1008	
14	1826	9437	13.7	689	126 55	138200 163	345	4720	1198	3.93
15	1742	5976	16.3	367		116600 192			170	

Bloo
Length 7.94' Weigh

Pass No	Temp °F	Total HPsec per pass.	Time of pass Sec	HPrate per pass	LL an Dri Loss HP
1	2090	3146	2.7	1165	
2	2090	2202	2.9	759	12 6
3	2049	2202	2.9	759	
4	2040	2674	3.3	810	12 7
5	2005	3460	3.9	887	
6	1965	3460	4.1	844	12 7
7	1972	4718	4.8	993	
8	1965	5347	5.4	990	12 10
9	1950	3460	6.5	532	
10	1905	3932	7.2	546	12 4
11	1866	5347	7.9	677	
12	1853	6920	9.9	713	12 5
13	1830	7777	11.9	595	
14	1826	8493	13.7	620	12 4
15	1728	5291	16.3	386	

Power Tests 22" 3 High Mills.

Kind of ba

R.P.M. of Mill:- 52.7

Bloom No. 1
Length 8.42' Weight 1851 Volume 6548 c.i.

Pass No.	Temp °F	Total HPsec per pass.	Time of pass Sec	HPrate per pass	LL and Drive Losses HP	Calc. Neck Fricf HP.	Net Rolling HP	Net HPsec.	Volume Displ Cu In	HPsec Cu in
1		1887	2.3	820					421	
2	2075	1573	2.7	583	16 98	210500 7	462	1245	773	1.61
3		1258	2.8	449					897	
4	2038	2045	3.2	639	16 106	223700 7	510	1630	930	1.76
5		2045	3.4	601					755	
6	1988	3146	4.2	611	16 102	238500 7	486	2040	1123	1.82
7		2359	4.6	513					1081	
8	1931	3303	5.4	612	16 102	175400 6	488	2640	1247	2.12
9		2202	6.3	334					299	
10	1884	2359	6.8	347	16 57	131700 4	270	1840	1027	1.79
11		4089	7.9	518					1000	
12	1835	4718	9.5	497	16 88	187900 6	392	3730	1288	2.89
13		4662	11.9	476					1067	
14	1777	5976	14.0	427	16 71	178300 6	334	4670	1267	3.70
15		2516	15.9	153					180	

Bloom No. 2
Length 8.45' Weight 1860 Volume 6571 c.i.

Pass No	Temp °F	Total HPsec per pass	Time of Pass Sec	HPrate per pass	LL and Drive Losses HP	Calc Neck Fricf HP	Net Rolling HP	Net HPsec	Volume Displ Cu In.	HPsec Cu in
1		2202	2.3	957					423	
2	2064	1573	2.6	604	16 101	199300 6	481	1250	777	1.61
3		1573	2.8	562					900	
4	2021	2202	3.1	710	16 118	219500 7	569	1765	933	1.89
5		1787	3.9	484					756	
6	1972	3146	4.0	786	16 131	217800 7	632	2530	1127	2.24
7		2516	4.6	547					1084	
8	1926	3539	5.4	655	16 109	148300 4	526	2840	1251	2.27
9		2045	6.5	315					299	
10	1872	2280	6.8	335	16 55	151800 5	259	1760	1032	1.71
11		4246	8.0	531					1003	
12	1816	5347	9.5	563	16 94	209300 6	447	4250	1292	3.28
13		5190	11.8	440					1071	
14	1763	5606	14.6	452	16 77	197300 6	353	5160	1271	4.05
15		2516	16.1	156					181	

Bloo
Length 8.53' Weigh

Pass No.	Temp °F	Total HPsec per pass.	Time of pass Sec	HPrate per pass	LL an Dri Loss HP
1		2092	2.3	909	
2	2085	1651	2.6	635	16 10
3		1274	2.8	455	
4	2043	2233	3.3	677	16 11
5		2029	3.6	564	
6	1988	2925	4.3	680	16 11
7		2516	4.7	535	
8	1938	3554	5.5	646	16 10
9		2013	6.5	310	
10	1884	2139	7.2	297	16 4
11		5033	7.6	662	
12	1737	8021	9.6	836	16 14
13		7140	11.7	610	
14	1681	7077	14.2	498	16 8
15		3775	16.5	222	

FIG. 24.

...high Mills. Kind of bearings :- Plain

...2.

...olume 6191 c.i. | Bloom No. 13 Length 7.94' Weight 1746 Volume 6175 c.i.

Net HPsec	Volume Displ Cu In.	HPsec Cu in	Pass No	Temp °F	Total HPsec per pass.	Time of pass Sec	HPrate per pass	LL and Drive Losses HP	Calc Neck Fricf HP	Net Rolling HP.	Net HPsec.	Volume Displ'd Cu In.	HPsec. cu in
	398		1	2090	3146	2.7	1165		223800 367			397	
	732		2	2090	2202	2.9	759	126 61	173800 144	428	1242	730	1.71
	848		3	2049	2202	2.9	759		193000 328			846	
845	880	2.1	4	2040	2674	3.3	810	126 71	186200 152	461	1520	878	1.73
	714		5	2005	3460	3.9	887		212000 348			711	
915	1061	1.81	6	1965	3460	4.1	844	126 77	198300 163	478	1960	1058	1.85
	1019		7	1972	4718	4.8	993		221000 362			1016	
280	1177	2.79	8	1965	5347	5.4	990	126 102	173400 142	620	3350	1173	2.85
	281		9	1950	3460	6.5	532		136300 225			281	
595	974	1.64	10	1905	3932	7.2	546	126 41	147000 121	258	1860	971	1.92
	945		11	1866	5347	7.9	677		179600 295			942	
420	1217	2.81	12	1853	6920	9.9	713	126 57	133300 164	366	3550	1213	2.93
	1008		13	1830	7777	11.9	595		184400 302			1004	
720	1198	3.93	14	1826	8493	13.7	620	126 47	193300 159	288	3942	1195	3.30
	170		15	1728	5291	16.3	386		114600 188			170	

...high Mills. Kind of bearings :- Timken

...2.7

...olume 6571 c.i. | Bloom No. 3 Length 8.53' Weight 1877 Volume 6633 c.i.

Net HPsec	Volume Displ Cu In.	HPsec Cu in	Pass No.	Temp °F	Total HPsec per pass.	Time of pass Sec	HPrate per pass	LL and Drive Losses HP	Calc Neck Fricf HP	Net Rolling HP.	Net HPsec	Volume Displ'd Cu In	HPsec cu in
	423		1		2092	2.3	909					427	
250	777	1.61	2	2085	1651	2.6	635	16 106	212800 7	506	1315	784	1.68
	900		3		1274	2.8	455					908	
765	933	1.89	4	2043	2233	3.3	677	16 113	212000 7	541	1785	943	1.89
	756		5		2029	3.6	564					764	
530	1127	2.24	6	1988	2925	4.3	680	16 113	224000 7	544	2340	1138	2.06
	1084		7		2516	4.7	535					1095	
840	1251	2.27	8	1938	3554	5.5	646	16 108	148300 4	518	2845	1260	2.26
	299		9		2013	6.5	310					302	
760	1032	1.71	10	1884	2139	7.2	297	16 49	131700 4	228	1642	1041	1.57
	1003		11		5033	7.6	662					1012	
250	1292	3.28	12	1737	8021	9.6	836	16 141	275300 8	671	6430	1305	4.93
	1071		13		7140	11.7	610					1079	
160	1271	4.05	14	1681	7077	14.2	498	16 83	205300 6	393	5580	1281	4.35
	181		15		3775	16.5	222					182	

Power Tests 22" 3 High Mills.

Kind of be

R.P.M. of Mill:- 61.0

Bloom No. 14 Length 7.98' Weight 1625 Volume 5740 c.i.										
Pass No.	Temp of	Total HPsec per pass.	Time of pass Sec.	HPrate per pass	LL and Drive Losses HP	Calc. Neck Fricf HP.	Net Rolling HP	Net HPsec.	Volume Displ Cu In	HPsec Cu.in
1	2100	3775	2.3	1641	158	251140			369	
2		2359	2.3	1026	126 108	192130 184	608	1398	679	2.05
3	2060	2830	2.4	1180	126	210753			786	
4	2050	2674	2.9	922	126 90	203923 200	506	1467	816	1.79
5	2016	2831	3.0	944	126	218241			662	
6	2040	3932	3.4	1156	126 129	210655 201	700	2380	984	2.41
7	1983	5033	3.8	1324	126	245376			947	
8	1965	6212	4.5	1381	126 167	215216 210	878	3951	1090	3.59
9	1961	3932	5.3	742	126	142902			261	
10	1917	3932	5.5	715	126 109	156943 150	330	1815	903	2.01
11	1890	5976	6.4	934	126	185232			877	
12	1853	7077	7.6	931	126 92	205126 197	516	3922	1128	3.48
13	1842	8021	9.2	872	126	186794			935	
14	1840	9122	10.9	837	126 130	194160 186	395	4306	1114	3.86
15	1714	5819	12.8	455	126	112449			158	

Bloom No. 15 Length 7.94' Weight 1746 Volume 6175 c.i.										
Pass No	Temp of	Total HPsec. per pass	Time of Pass Sec	HPrate per pass	LL and Drive Losses HP	Calc Neck Fricf HP	Net Rolling HP.	Net HPsec	Volume Displ Cu. In.	HPsec Cu in
1	2100	3460	2.0	1730	158	238043			397	
2	2070	2831	2.4	1180	158 130	197835 190	702	1685	730	2.28
3	2070	2831	2.5	1132	158	218598			846	
4	1998	2831	3.0	944	158 92	217665 208	486	1458	877	1.66
5	2016	3146	3.2	983	158	221351			711	
6	1976	4089	3.5	1168	189 125	210655 201	653	2286	1058	2.16
7	1983	5033	3.8	1324	158	238632			1016	
8	1941	6605	5.0	1321	189 152	193037 184	796	3980	1173	3.39
9	1914	4089	5.5	743	189	134121			281	
10	1905	3932	6.0	655	189 93	145695 138	235	1410	971	1.45
11	1890	5898	6.5	907	189	179563			942	
12	1879	6920	7.8	887	189 98	192672 185	435	3393	1213	2.79
13	1817	8021	9.6	836	158	177693			1004	
14	1826	9751	11.4	855	158 129	185751 178	390	4446	1195	3.72
15	1728	6291	13.3	473	158	106140			170	

Bloom Length 7.5 Weight					
Pass No.	Temp of	Total HPsec per pass	Time of pass Sec	HPrate per pass	LL and Drive Losses HP
1	2110	3743	2.0	1872	12
2	2070	2862	2.3	1245	189 193
3	2080	3114	2.5	1246	158
4	1987	3460	2.9	1193	185 125
5	2016	3677	3.0	1226	158
6	1965	4262	3.4	1254	158 143
7	1961	5347	3.75	1426	158
8	1917	6086	4.4	1383	158 160
9	1902	4278	5.2	823	185
10	1892	4246	5.6	758	22 10
11	1866	5284	6.5	813	15
12	1840	7062	7.75	911	12 85
13	1804	8304	9.3	893	12
14	1798	9751	11.0	886	12 8
15		5379	12.0	448	15

Power Tests 22" 3 High Mills.

Kind of be

R.P.M. of Mill:- 63.2

Bloom No. 8 Length 8.05' Weight 1771 Volume 6260 c.i.										
Pass No	Temp of	Total HPsec per pass.	Time of pass Sec	HPrate per pass	LL and Drive Losses HP	Calc Neck Fricf HP	Net Rolling HP	Net HPsec.	Volume Displ Cu In	HPsec Cu in
1		2359	2.0	1179	13				403	
2	2090	1730	2.2	786	32 129	190660 6	619	1362	740	1.84
3		1415	2.5	565	32				858	
4	2048	2044	2.5	818	32 135	232780 6	645	1613	889	1.81
5		1887	3.1	608	13				722	
6	2005	2831	3.5	807	32 133	201025 6	636	2226	1073	2.07
7		2438	4.1	594	32				1034	
8	1966	3066	4.6	666	32 110	115578 4	520	2392	1191	2.00
9		1887	5.6	337	32				285	
10	1938	2123	6.0	354	32 56	111660 4	262	1572	984	1.59
11		3539	7.0	505	32				955	
12	1908	4797	8.4	570	32 93	167963 5	440	3696	1232	3.00
13	.	4718	10.2	462	63				1021	
14	1833	5190	12.3	422	13 68	153448 5	336	4133	1212	341
15		2516	14.5	240	13				172	

Bloom No. 6 Length 7.95' Weight 1750 Volume 6182 c.i.										
Pass No	Temp of	Total HPsec per pass	Time of Pass Sec	HPrate per pass	LL and Drive Losses HP	Calc Neck Fricf HP	Net Rolling HP	Net HPsec	Volume Displ Cu In.	HPsec Cu in
1		2391	2.0	1196	13				398	
2	2100	1699	2.2	772	13 129	212680 7	623	1371	732	1.87
3		1415	2.3	615	13				848	
4	2059	1950	2.6	750	13 125	210825 7	605	1573	878	1.79
5		1799	3.0	600	13				714	
6	2016	2674	3.4	786	13 131	218349 7	635	2159	1059	2.03
7		2453	3.8	646	13				1021	
8	1977	3146	4.5	700	13				1177	
9		1793	5.2	345	13				281	
10	1942	1982	5.8	342	13 56	83291 2	271	1572	971	1.61
11		6585	6.3	1011	13				943	
12	1908	3460	8.2	422	13 68	117749 4	337	2763	1217	2.27
13		4970	10.1	492	13				1008	
14	1853	3664	12.1	302	13 49	102690 3	237	2868	1197	2.39
15		2800	14.0	200	13				170	

Bloom Length 8.28' Weigh					
Pass No.	Temp of	Total HPsec per pass	Time of pass Sec	HPrate per pass	LL and Drive Losses HP
1		2045	2.2	928	13
2	2085	1730	2.3	752	13 12
3		1415	2.5	566	13
4	2043	2280	2.8	814	13 13
5		1887	3.2	589	13
6	1999	2674	3.6	742	13 12
7		2359	4.3	548	13
8	1972	3303	5.0	661	3
9		2123	5.8	366	6
10	1944	2359	6.2	380	3 6
11		3775	6.9	547	6
12	1896	4718	8.2	576	3 9
13		4718	10.5	449	1
14	1829	6291	12.7	495	3 6
15		2674	14.2	188	6

FIG. 25.

High Mills. Kind of bearings :- Plain

61.0

5 Volume 6175 c.i.

Bloom No. 16 Length 7.5 Weight 1650 Volume 5833 c.i.

	Net HPsec	Volume Displ. Cu. In.	HPsec Cu in	Pass No.	Temp °F	Total HPsec per pass.	Time of pass Sec	HPrate per pass	LL and Drive Losses HP	Calc Neck Fricf HP	Net Rolling HP	Net HPsec.	Volume Displ Cu In.	HPsec Cu in
		397		1	2110	3743	2.0	1872	126	262150			375	
	1685	730	2.28	2	2070	2862	2.3	1245	189 139	197635 190	727	1672	690	2.39
		846		3	2080	3114	2.5	1246	158	222580			799	
	1458	877	1.66	4	1987	3460	2.9	1193	189 129	213745 205	670	1943	829	2.34
		711		5	2016	3677	3.0	1226	158	227668			673	
	2286	1058	2.16	6	1965	4262	3.4	1254	158 143	223090 214	739	2513	999	2.51
		1016		7	1961	5347	3.75	1426	158	243128			961	1
	3980	1173	3.39	8	1917	6086	4.4	1383	158 166	208745 200	859	3780	1108	3.41
		281		9	1902	4278	5.2	823	189	125392			265	
	1410	971	1.45	10	1892	4246	5.6	758	220 108	147008 141	289	1618	916	1.77
		942		11	1866	5284	6.5	813	158	182398			890	
	3393	1213	2.79	12	1840	7062	7.75	911	126 89	202615 195	501	3883	1147	3.38
		1004		13	1804	8304	9.3	893	126	186794			949	
	4446	1195	3.72	14	1798	9751	11.0	886	126 84	134160 186	490	5390	1129	4.77
		170		15		5379	12.0	448	158				160	

High Mills. Kind of bearings :- Timken

63.2

6 Volume 6182 c.i.

Bloom No. 7 Length 8.28' Weight 1825 Volume 6447 c.i.

	Net HPsec	Volume Displ Cu In.	HPsec Cu in	Pass No.	Temp °F	Total HPsec per pass	Time of pass Sec	HPrate per pass	LL and Drive Losses HP	Calc Neck Fricf HP	Net Rolling HP	Net HPsec	Volume Displ Cu In	HPsec Cu in
		398		1		2045	2.2	928	13				414	
	1371	732	1.87	2	2085	1730	2.3	752	13 125	218690 7	607	1396	761	1.83
		848		3		1415	2.5	566	13				882	
	1573	878	1.79	4	2043	2280	2.8	814	13 136	206703 7	658	1842	914	2.01
		714		5		1887	3.2	589	13				742	
	2159	1059	2.03	6	1999	2674	3.6	742	13 123	210351 7	599	2156	1103	1.95
		1021		7		2359	4.3	548	13				1064	
		1177		8	1972	3303	5.0	661	32				1223	
		281		9		2123	5.8	366	63				293	
	1572	971	1.61	10	1944	2359	6.2	380	32 61	95077 3	284	1761	1010	1.74
		943		11		3775	6.9	547	63				983	
	2763	1217	2.27	12	1896	4718	8.2	576	32 95	147878 5	444	3641	1264	2.88
		1008		13		4718	10.5	449	13				1050	
	2868	1197	2.39	14	1829	6291	12.7	495	32 80	157345 5	378	4801	1246	3.85
		170		15		2674	14.2	188	63				177	

Power Tests 22" 3 High Mills.

Kind of b

R.P.M. of Mill:- 71.

Bloom No. 6 — Length 8.13' — Weight 1790 — Volume 6323 c.i.

Pass No.	Temp °F	Total HP sec. per pass.	Time of pass Sec.	HP rate per pass	L.L. and Drive Losses HP	Calc. Neck Fricf HP	Net Rolling HP	Net HP sec.	Volume Displ'd Cu In	HP sec Cu in.
1	2080	4561	1.8	2534	189	256645			407	
2	2120	2831	2.0	1415	158 170	181120 203	884	1768	747	2.36
3	2049	2988	2.4	1245	158	210753			867	
4	2110	3460	2.6	1331	158 156	205900 230	787	2046	897	2.28
5	2027	3617	2.8	1292	158	221350			728	
6	1998	4404	3.3	1334	158 156	216873 243	777	2564	1085	2.36
7	1983	5190	3.9	1331	158	238632			1041	
8	1965	6763	4.2	1610	189 200	208343 234	987	4145	1201	3.45
9	1961	4089	5.1	802	158	120553			288	
10	1917	4404	5.75	766	158 114	153631 172	322	1852	994	1.86
11	1902	6291	6.3	999	158	182369			965	
12	1879	7706	7.4	1041	158 106	205126 230	547	4048	1245	3.25
13	1830	8100	8.8	920	158	182242			1029	
14	1853	10066	11.0	915	158 85	194160 218	454	4994	1223	4.08
15	1784	6055	12.75	475	158	108242			174	

Bloom No. 7 — Length 8.05' — Weight 1771 — Volume 6260 c.i.

Pass No	Temp °F	Total HP sec. per pass	Time of Pass Sec	HP rate per pass	L.L. and Drive Losses HP	Calc. Neck Fricf HP	Net Rolling HP	Net HP sec.	Volume Displ. Cu In.	HP sec Cu in
1	2070	3303	1.9	1738	158	223615			403	
2	2110	2123	2.0	1062	158 109	159100 178	617	1234	740	1.65
3	2049	2910	2.3	1265	158	202908			857	
4	2070	3224	2.6	1240	158 140	194135 218	724	1882	889	2.11
5	2027	2988	2.8	1067	158	205906			722	
6	2030	3853	3.1	1243	158 140	201368 225	720	2232	1073	2.08
7	1902	5190	3.6	1442	158	234136			1031	
8	1965	6291	4.4	1430	158 172	230086 258	842	3705	1187	3.12
9	1866	4404	4.9	899	158	142902			285	
10	1905	4718	5.5	858	158 130	163566 183	387	2129	985	2.16
11	1778	6763	6.3	1073	158	199410			954	
12	1840	8650	7.3	1185	158 131	213169 241	655	4782	1232	3.88
13	1735	9122	8.9	1025	158	198171			1019	
14	1826	10066	10.5	959	158 93	213181 241	467	4904	1212	4.04
15	1756	6606	12.8	516	158	116652			172	

Bloo — Length 8.13' — Weigh

Pass No.	Temp °F	Total HP sec. per pass.	Time of pass Sec	HP rate per pass	
1	2110	4011	2.0	2005	
2	2120	2705	2.1	1288	
3	2080	3271	2.3	1422	
4	2080	3633	2.6	1397	
5	2060	3979	2.9	1372	
6	2020	4325	3.3	1311	
7	1961	5426	3.8	1428	
8	1965	6779	4.4	1541	
9	1890	4388	4.9	896	
10	1905	4467	5.6	798	
11	1842	6967	6.5	1072	
12	1866	7257	7.4	981	
13	1791	9153	9.5	964	
14	1826	10852	11.0	987	
15	1742	6606	12.75	518	

FIG.26—PLATE V.

Power Tests 22" 3 High Mills.

Kind of b

R.P.M. of Mill:- 75.2

Bloom No. 14 — Length 8.5' — Weight 1870 — Volume 6600 c.i.

Pass No	Temp °F	Total HP sec per pass	Time of pass Sec	HP rate per pass	L.L. and Drive Losses HP	Calc Neck Fricf HP	Net Rolling HP	Net HP sec.	Volume Displ Cu In	HP sec Cu in
1		2595	1.7	1526	16				425	
2	2105	2123	1.9	1117	16 133	212680 8	960	1824	825	2.21
3		2045	2.0	1022	16				904	
4	2058	2674	2.4	1114	16 127	214548 8	963	2311	938	2.46
5		2595	2.5	1038	16				762	
6	2005	3460	3.3	1049	16 121	210391 8	904	2983	1133	2.63
7		2988	3.6	830	16				1090	
8	1966	3775	4.3	878	16 93	212014 5	764	3285	1256	2.61
9		2202	4.8	459	16				301	
10	1932	2438	5.1	478	16 79	211787 3	380	1938	1038	1.86
11		4246	5.6	758	16				1009	
12	1884	4876	6.6	739	16 123	213213 5	595	3927	1302	3.01
13		5426	8.5	638	16				1076	
14	1842	5819	10.1	576	16 95	212814 5	460	4646	1279	3.62
15		2831	11.5	246	16				182	

Bloom No. 15 — Length 8.05' — Weight 1771 — Volume 6260 c.i.

Pass No	Temp °F	Total HP sec per pass	Time of Pass Sec	HP rate per pass	L.L. and Drive Losses HP	Calc Neck Fricf HP	Net Rolling HP	Net HP sec	Volume Displ Cu In	HP sec Cu in
1		2674	1.8	1485	16				403	
2	2105	1887	1.8	1048	16 121	212360 8	903	1625	740	2.16
3		1809	2.1	861	16				858	
4	2058	2674	2.5	1069	16 125	214548 8	920	2300	889	258
5		2516	2.8	899	16				722	
6	2005	3303	3.0	1101	16 131	225839 8	946	2838	1073	2.64
7		2910	3.5	831	16				1034	
8	1977	3460	3.9	887	16				1191	
9		2438	4.4	554	16				285	
10	1913	2674	5.1	524	16 86	214943 5	417	2127	984	2.16
11		4640	5.6	829	16				955	
12	1842	5583	6.6	846	16 142	170472 6	682	4501	1232	365
13		5819	8.5	685	16				1021	
14	1783	6606	10.3	641	16 106	180418 6	513	5284	1212	4.36
15		2831	12.5	226	16				172	

Bloo — Length 8.5' — Weigh

Pass No.	Temp °F	Total HP sec per pass	Time of pass Sec	HP rate per pass	
1		2312	1.7	1360	
2	2104	1903	2.1	906	
3		1761	2.1	839	
4	2059	2674	2.6	1028	
5		2548	2.8	910	
6	2021	3240	2.9	1117	
7		2847	3.3	863	
8	1983	3822	4.1	932	
9		1950	4.8	406	
10	1938	2469	5.3	466	
11		4246	5.7	745	
12	1894	4105	7.0	586	
13		4561	8.6	530	
14	1835	6197	10.4	596	
15		1337	12.6	106	

ligh Mills. Kind of bearings :- Plain

lume 6260 c.i. | Bloom No. 8 — Length 8.13' Weight 1790 Volume 6323 c.i.

Net Psec.	Volume Displ. Cu In.	HPsec Cu in	Pass No.	Temp °F	Total HPsec per pass.	Time of pass Sec	HPrate per pass	LL and Drive Losses HP	Calc Neck Fricf HP	Net Rolling HP.	Net HPsec.	Volume Displ Cu In.	HPsec cu in
	403		1	2110	4011	2.0	2005	153	256845			407	
234	740	1.65	2	2120	2705	2.1	1288	153 149	249090 166	815	1712	747	2.29
	857		3	2080	3271	2.3	1422	158	214635			867	
382	889	2.11	4	2080	3633	2.6	1397	158 167	209823 234	838	2179	897	2.42
	722		5	2060	3979	2.9	1372	158	218241			728	
232	1073	2.08	6	2020	4325	3.3	1311	158 152	213769 240	761	2511	1085	2.31
	1031		7	1961	5426	3.8	1428	158	247684			1041	
705	1187	3.12	8	1965	6779	4.4	1541	158 191	230086 258	934	4110	1201	342
	285		9	1890	4388	4.9	896	158	131429			288	
129	985	2.16	10	1905	4467	5.6	798	158 119	160256 179	342	1915	994	1.93
	954		11	1842	6967	6.5	1072	158	141865			965	
782	1232	3.88	12	1866	7257	7.4	981	158 96	217680 244	483	3574	1245	2.87
	1019		13	1791	9153	9.5	964	158	193620			1029	
904	1212	4.04	14	1826	10852	11.0	987	158 97	210976 236	496	5456	1223	4.46
	172		15	1742	6606	12.75	518	158	118753			174	

ligh Mills. Kind of bearings :- Timken

:2

lume 6260 c.i. | Bloom No. 16 — Length 8.5' Weight 1870 Volume 6600 c.i.

Net Psec	Volume Displ Cu In	HPsec Cu in	Pass No.	Temp °F	Total HPsec per pass.	Time of pass Sec	HPrate per pass	LL and Drive Losses HP	Calc Neck Fricf HP	Net Rolling HP.	Net HPsec.	Volume Displ Cu In.	HPsec cu in
	403		1		2312	1.7	1360	16				425	
525	740	2.16	2	2104	1903	2.1	906	16 96	212680 8	786	1651	825	2.00
	858		3		1761	2.1	839	16				904	
300	889	2.58	4	2059	2674	2.6	1028	16 117	218470 8	887	2306	938	2.46
	722		5		2548	2.8	910	16				762	
838	1073	2.64	6	2021	3240	2.9	1117	16 133	219678 8	960	2784	1133	2.46
	1034		7		2847	3.3	863	16				1090	
	1191		8	1983	3822	4.1	932	16 102	121014 5	809	3317	1256	2.64
	285		9		1950	4.8	406	16				301	
127	984	2.16	10	1938	2469	5.3	466	16 78	35100 4	368	1950	1038	1.88
	955		11		4246	5.7	745	16				1009	
501	1232	3.65	12	1884	4105	7.0	586	16 98	152898 6	466	3262	1302	2.50
	1021		13		4561	8.6	530	16				1076	
284	1212	4.36	14	1835	6197	10.4	596	16 100	170472 6	474	4930	1279	3.85
	172		15		1337	12.6	106	16				182	

Power Tests 22" 3 High Mills.

Kind of be

R.P.M. of Mill:- 83.5

Bloom No. 5 — Length 8.0' — Weight 1760 — Volume 6222 c.i.

Pass No.	Temp of	Total HP sec per pass.	Time of pass Sec	HP rate per pass	LL and Drive Losses HP	Calc. Neck Fricl HP	Net Rolling HP	Net HP sec	Volume Displ Cu. In.	HP sec Cu. In
1	2070	4560	1.75	2610	252	229130 605			400	
2	2050	3145	1.75	1796	252 226	170110 224	1094	1914	735	2.6
3	2038	3540	1 8	1968	252	190390 527			852	
4	2009	4420	2.0	2210	252 296	174520 231	1431	2862	884	3.24
5	2005	3940	2.4	1640	252	218130 567			717	
6	1953	4560	2.8	1630	252 197	219380 291	890	2492	1066	2.34
7	1972	5660	2.9	1950	221	236620 630			1025	
8	1941	6760	3.3	2045	221 271	189614 251	1302	4297	1182	3.63
9	1950	4560	4.0	1140	252	125312 333			283	
10	1905	4720	4.25	1112	252 110	149350 197	553	2348	978	2.4
11	1878	6450	5.0	1290	252	179500 475			951	
12	1892	7860	6.0	1310	252 142	197430 260	656	3936	1223	3.21
13	1842	8810	7.3	1204	221	179330 475			1013	
14	1866	10060	8.8	1142	221 117	185840 245	559	4919	1204	4.07
15	1770	6130	10.7	572	252	114830 303			171	

Bloom No. 4 — Length 8.0' — Weight 1760 — Volume 6222 c.i.

Pass No.	Temp of	Total HP sec per pass	Time of Pass Sec.	HP rate per pass	LL and Drive Losses HP	Calc. Neck Fricl HP	Net Rolling HP	Net HP sec.	Volume Displ Cu. In.	HP sec Cu in
1	2090	4800	1.75	2740	252	251100 662			400	
2	2030	3460	1.8	1922	252 246	192100 254	1170	2106	735	2.87
3	2049	3300	2.0	1650	252	210750 556			852	
4	2009	4020	2 1	1914	189 251	233500 282	1192	2503	884	2.83
5	2027	4175	2.3	1813	252	224460 592			717	
6	1987	4800	2.6	1846	252 234	229100 302	1057	2748	1066	2.58
7	1972	5820	2.8	2080	252	238600 630			1025	
8	1941	7475	3.3	2264	189 310	194900 257	1508	4976	1182	4.21
9	1950	4560	4.0	1140	189	120500 319			283	
10	1917	4560	4.25	1073	252 104	149350 197	520	2210	978	2.26
11	1890	6700	5.0	1340	252	173800 459			951	
12	1892	8175	6.1	1340	252 148	197400 261	679	4142	1223	3.38
13	1830	8900	7.3	1220	252	175330 463			1013	
14	1866	10000	8.8	1137	252 112	185850 246	527	4638	1204	3.85
15	1798	6290	10.6	593	252	101900 269			171	

Bloo — Length 7.94' — Weight

Pass No	Temp of	Total HP sec per pass	Time of pass Sec	HP rate per pass	LL and Drive Losses HP
1	2080	4467	1.7	2627	252
2	2020	3444	18	1914	221 245
3	2049	3649	1.9	1920	221
4	1998	4215	2.2	1916	252 246
5	2027	4215	2.3	1833	252
6	1965	4876	2.5	1950	252 252
7	1983	5961	2.4	2484	252
8	1965	6826	3.2	2133	152 29
9	1950	4671	4.1	1139	252
10	1905	5017	4.3	1167	252 118
11	1878	6495	4.9	1326	221
12	1866	7990	6.3	1268	221 139
13	1842	9090	7.2	1263	252
14	1840	10317	8.6	1199	252 124
15	1770	6763	9.8	690	252

Power Tests 22" 3 High Mills.

Kind of be

R.P.M. of Mill:- 82.5

Bloom No. 11 — Length 8.23' — Weight 1810 — Volume 6400 c.i.

Pass No.	Temp of	Total HP sec per pass.	Time of pass Sec	HP rate per pass	LL and Drive Losses HP	Calc. Neck Fricl HP	Net Rolling HP	Net HP sec	Volume Displ Cu. In.	HP sec. Cu. In
1		2440	2.0	1220	32				412	
2	2095	2280	2 0	1140	63 133	201670 8	936	1872	758	2.47
3		2202	2 1	1050	63				878	
4	2053	2752	2 3	1194	63 143	218470 9	979	2252	910	2.47
5		2595	2.4	1080	32				738	
6	2005	3615	2.8	1288	63 158	216570 9	1058	2962	1097	2 7
7		2990	3.0	997	63				1057	
8	1972	4250	3.5	1211	63 145	121108 5	998	3493	1219	2.86
9		2520	4.0	629	63				291	
10	1938	2440	4.3	566	63 49	114330 5	449	1931	1006	1.92
11		4870	5.1	955	63				977	
12	1896	5420	6.4	847	63 83	151854 6	695	4448	12.58	3.54
13		4870	7.1	686	63				1044	
14	1847	6133	8.85	693	63 61	150394 6	563	4983	1239	4.02
15		2045	8 9	230	63				176	

Bloom No. 12 — Length 8.33' — Weight 1834 — Volume 6478 c.i.

Pass No.	Temp of	Total HP sec per pass	Time of Pass Sec.	HP rate per pass	LL and Drive Losses HP	Calc. Neck Fricl HP	Net Rolling HP	Net HP sec.	Volume Displ. Cu In.	HP sec Cu in
1		3615	1.8	2020	63				417	
2	2080	2830	1.8	1571	63 206	212680 9	1293	2327	766	3.02
3		2045	1.9	1076	63				887	
4	2032	3460	1.9	1821	95 246	245550 10	1470	2793	919	3.04
5		3770	2.3	1638	63				747	
6	1983	4400	2.6	1695	63 228	236930 10	1394	3624	1109	3.27
7		4080	3.0	1362	32				1069	
8	1938	4950	3.5	1415	32 183	164406 7	1193	4176	1233	3.39
9		2910	4.0	728	63				295	
10	1896	3145	4.3	732	63 65	124706 5	599	2577	1017	2.53
11		5510	5.1	1080	63				988	
12	1860	6360	6.1	1042	63 115	183330 7	857	5228	1273	4.11
13		7000	7.3	960	63				1056	
14	1816	7150	8.7	822	63 80	168740 7	672	5846	1250	4.67
15		2830	8.9	318	63				178	

Bloo — Length 8.3' — Weight

Pass No	Temp of	Total HP sec per pass	Time of pass Sec	HP rate per pass	LL and Drive Losses HP
1		3770	1.75	2152	32
2	2095	2670	1.9	1404	63 178
3		2360	1.9	1242	95
4	2053	3460	2.2	1571	63 20
5		2660	2.4	1106	32
6	2005	4020	2.8	1437	63 18
7		3770	3.0	1257	63
8	1966	4720	3.5	1347	32 17
9		2910	4.1	709	32
10	1932	2990	4.3	695	63 63
11		5120	5.0	1024	63
12	1890	5900	5.7	1034	63 11
13		6610	7.5	881	63
14	1848	4400	8.0		63
15		3540	8.8	403	63

FIG. 27.

h Mills. Kind of bearings :- Plain

Bloom No. 3

e 6222 c.i. Length 7.94' Weight 1746 Volume 6175 c.i.

Volume Displ Cu In.	HPsec Cu in	Pass No.	Temp °F	Total HPsec. per pass.	Time of pass Sec	HP rate per pass	LL and Drive Losses HP	Calc Neck Fricf HP	Net Rolling HP.	Net HPsec.	Volume Displ Cu In	HPsec cu in
400		1	2080	4467	1.7	2627	252	240130 634			397	
735	2.87	2	2020	3444	1.8	1914	221 249	1811E0 239	1205	2169	730	2.97
852		3	2049	3649	1.9	1920	221	206830 546			846	
884	2.83	4	1998	4215	2.2	1916	252 246	213750 283	1135	2497	878	2.84
717		5	2027	4215	2.3	1833	252	224460 592			711	
1066	2.58	6	1965	4876	2.5	1950	252 252	229300 302	1144	2860	1058	2.71
1025		7	1983	5961	2.4	2484	252	240880 636			1016	
1182	4.21	8	1965	6826	3.2	2133	158 291	184340 243	1441	4611	1173	3.93
283		9	1950	4671	4.1	1139	252	123910 333			281	
978	2.26	10	1905	5017	4.3	1167	252 118	143600 190	607	2610	971	2.69
951		11	1878	6495	4.9	1326	221	167620 444			942	
1223	3.38	12	1866	7990	6.3	1268	221 139	202400 268	640	4032	1213	3.32
1013		13	1842	9090	7.2	1263	252	182000 480			1004	
1204	3.85	14	1840	10317	8.6	1199	252 124	187600 248	575	4945	1195	4.13
171		15	1770	6763	9.8	690	252	106000 280			170	

h Mills. Kind of bearings :- Timken

Bloom No. 13

e 6478 c.i. Length 8.3' Weight 1826 Volume 6450 c.i.

Volume Displ. Cu In.	HPsec Cu in	Pass No.	Temp °F	Total HPsec. per pass.	Time of pass Sec	HP rate per pass	LL and Drive Losses HP	Calc Neck Fricf HP	Net Rolling HP.	Net HPsec.	Volume Displ Cu In.	HPsec. cu in
417		1		3770	1.75	2152	32				415	
766	3.02	2	2095	2670	1.9	1404	63 178	226282 9	1154	2194	763	2.88
887		3		2360	1.9	1242	95				885	
919	3.04	4	2053	3460	2.2	1571	63 207	234160 9	1292	2842	917	3.10
747		5		2660	2.4	1106	32				744	
1109	3.27	6	2005	4020	2.8	1437	63 184	235220 9	1181	3307	1105	2.99
1069		7		3770	3.0	1257	63				1064	
1233	3.39	8	1966	4720	3.5	1347	32 171	169438 7	1137	3980	1228	3.24
295		9		2910	4.1	709	32				293	
1017	2.53	10	1932	2990	4.3	695	63 62	101539 4	566	2434	1013	2.4
988		11		5120	5.0	1024	63				985	
1273	4.11	12	1890	5900	5.7	1034	63 115	152811 6	850	4845	1270	3.82
1056		13		6610	7.5	881	63				1050	
1250	4.67	14	1848	4400	8.0		63	140420 6			1249	
178		15		3540	8.8	403	63				178	

Synchronous Motor Driving Hammer-Mill at Central Alloy Steel Co., Improves Power Factor

By C. E. BUCHAN*

Advantages of High Power Factor

The most efficient operation of alternating-current generating and distribution equipment is largely dependent on keeping power factor comparatively high. Circulation of large amounts of lagging reactive power between low power factor loads and the generator reduces the available generator capacity. It also decreases generator efficiency. Distribution equipment suffers also in reduction of available kilowatt capacity; distribution line copper losses are greater than if the power factor of the same load were high. In addition, low power factor may be accompanied by lower than rated voltage at load terminals.

The reduction of the permissible kilowatt load on the generator because of low power factor, is more pronounced where diversity between connected kilowatt load and generator kilowatt capacity is small. A low diversity factor is usually the case where power is privately generated. Hence it is of particular importance where power is generated on the manufacturing premises that power factor conditions be improved wherever drives allow the use of high rather than low power factor motors.

Unity and leading power factor synchronous motors can be used wherever they can be suitably applied. They should be considered first on constant speed drives over 20 hp. Synchronous condensers can be used where the size of load warrants or capacitors can be used where particular conditions show their use most economical.

Synchronous Motor Drive Selected

Need of power factor correction and guaranteed performance on a severe drive, resulted in a selection by the Central Alloy Steel Corporation engineers, of a synchronous motor to drive a hammermill. The hammermill is in operation at the coal handling plant of the Central Furnace Division of the Central Alloy Steel Corporation at Massillon, O., where it runs in conjunction with a Bradford breaker crushing coal for the coke ovens.

Heretofore the wound-rotor induction motor had been considered a standard application for this type of drive because of the high starting duty imposed by the heavy weight and large inertia of the hammermill rotor. Another characteristic of the drive, which heretofore had made the success of the synchronous motor uncertain, was the possibility of a temporary shutdown of power supply in which case the motor might have to be started with coal in the mill. The motor is driving a Pennsylvania crusher, size SXT-100, equipped with 200 hammers, each 13½" in length and having a 42" diameter hammer circle. The crusher handles approximately 1200 tons of coal per ten hour day or 120 tons per hour. Pocahontas coal is used and it is comparatively easily crushed, although when the coal is wet a considerably greater load is imposed on the motor.

The use of a synchronous motor was considered primarily for reasons of power factor. When an induction motor is applied to this drive, it must be of such horsepower rating as to insure starting and bring the mill up to speed. This results in an oversize motor and because a great deal of the operation is at part and even no load, an induction motor would operate at a very low average power factor.

The coal handling plant is at the end of a 2300-volt line about 1000 feet from the power house. The motor equipment in the coal handling plant and in the coke ovens consists of squirrel-cage induction motors so that the overall power factor in this division of the plant was approximately .60. Obviously the application of an induction motor to the hammermill would have meant a still lower power factor.

The Central Furnace Division of the Central Alloy Steel Corporation manufactures the greater part of its own power, by using blast-furnace gas for firing the boilers. Power in excess of the plant generating capacity is furnished by the Ohio Public Service Company. To most efficiently use the power generating equipment, it was necessary to make provision for an overall high power factor in the coal-handling plant and the coke ovens, so the synchronous motor driving the hammermill was selected to improve the total power factor on the coke oven feeder from approximately .60 to .90.

If reactive current were obtained from the generator at the plant there would have been considerable limitation in the kilowatt output, and lowered efficiency, from the generators.

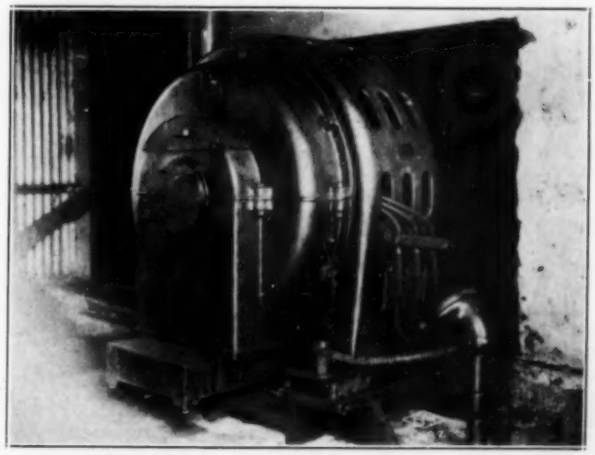


FIG. 1.

The synchronous motor applied to the hammermill (See Figure 1) is a 300 hp., .80 leading power factor, 900 r.p.m., 2300-volt, 3-phase, 60-cycle motor. The motor was specially designed with a double-cage starting winding which insures high starting torque

*Engineer, Electric Machinery Mfg. Co., Milwaukee, Wis.

and pull-in torque. The mechanical design was made especially rugged to withstand the vibration and variable loads imposed on it.

As will be noted from Figure 1, the motor is of semi-enclosed construction, ventilation being obtained by fans on the rotor. Air is drawn through a vent in the end bracket of the motor and is blown out through the openings in the stator. A filter in the vent opening prevents entrance of coal dust into the motor.

The starter is automatic, reduced-voltage, oil-break type, with a frequency-relay actuated switch for applying direct-current field excitation to the motor. The frequency relay control permits accurate application of field excitation at the correct motor speed, regardless of the time for getting up to speed

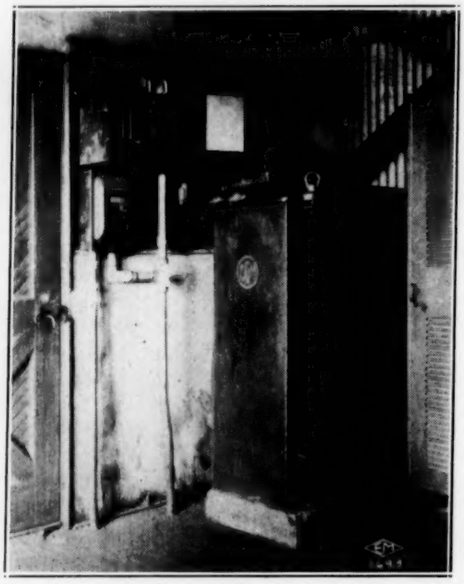


FIG. 2.

or the load on the motor. It also permits resynchronization of the motor should it be pulled out of step by a momentary peak load. The frequency relay field control is shown in the open box in the upper left hand corner of Figure 2.

Charts Show Results Obtained

The graphic wattmeter chart in Figure 3A shows the load on the coke plant circuit. At low loads

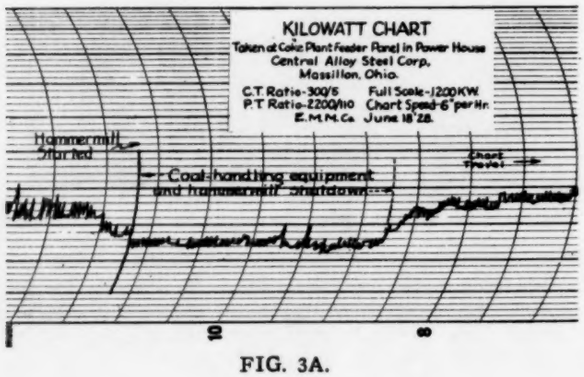


FIG. 3A.

and with .80 power factor field excitation, the motor operates at a leading power factor and, as shown on the power factor chart 3B, always maintains the average power factor of the coke plant feeder at approximately .90 as against .60 when the synchronous motor is shut down.

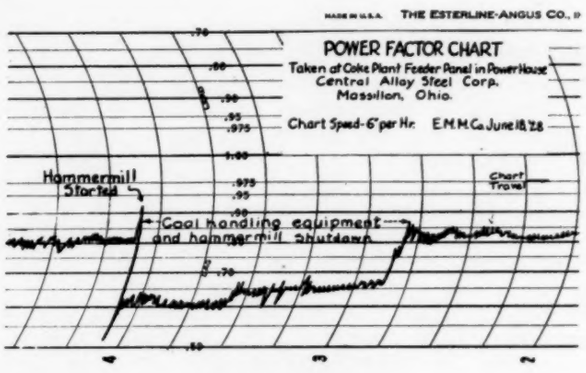

THE ESTERLINE-ANGUS CO.
POWER FACTOR CHART
Taken at Coke Plant Feeder Panel in Power House
Central Alloy Steel Corp.
Massillon, Ohio.
Chart Speed-6" per Hr. E.M.M.Co. June 18'28
Hammermill Started
Coal handling equipment and hammermill shutdown
Chart Travel

FIG. 3B.

The motor starts the mill and accelerates it to synchronous speed in approximately 20 seconds. It was found that in case of an interruption to the power supply while the plant was in operation, that the automatic coal feed would shut off the coal supply and the inertia of the hammermill would clear the mill entirely of coal, meaning of course, that the motor could then be started with no load in the mill. The motor is so constructed, however, that in case the mill is accidently filled with coal when in a stationary position, it will be possible to start the motor on full line voltage. With full-voltage starting the motor develops sufficient torque to bring the hammermill rotor up to speed and clear the mill of coal.

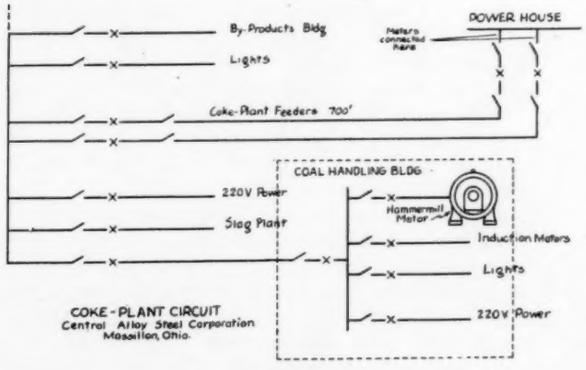


FIG. 3C.

The first advantage arising from the use of a synchronous motor on the hammermill is improvement of power factor of the coke plant and the release of generator capacity. The power factor improvement resulting from the use of a synchronous motor on this crusher, in place of the usual induction motor is obvious from the following tabulation:

Type of Motor	Load	Power Factor	Reactive kv-a at zero p.f.
Induction	4/4	.91 lagging	111 lagging
Synchronous	4/4	.80 leading	180 leading
			291 net gain
Induction	3/4	.87 lagging	105 lagging
Synchronous	3/4	.69 leading	191 leading
			296 net gain
Induction	1/2	.80 lagging	93 lagging
Synchronous	1/2	.51 leading	211 leading
			304 net gain

From the above tabulation it will be noted that over the entire range of operation to full load, the synchronous motor operates at leading power factor supplying a magnetizing current to the system. In contrast to this, the induction motor operates continually at lagging power factor. The efficiencies of the .80 power factor synchronous motor are slightly better than those of the induction motor. Hence approximately 300 kv-a in magnetizing capacity is obtained for no expenditure of power and therefore at 100% efficiency. The cost of the magnetizing capacity was low as it was only the amount by which the synchronous motor cost exceeded the cost of the induction motor. A second advantage is a material increase in production because of the absoultely constant speed of the synchronous motor.

Molybdenum Wound Hydrogen Furnaces for Copper Brazing

By C. M. THOMPSON*

The development of the Molybdenum Wound Hydrogen Furnace has covered a period of about twenty years. Its early use began with the research in tungstens for lamp filaments, but its exploitation has not been rapid although for laboratory and small industrial purposes these furnaces have been in use for alloy research, annealing, heat-treating and processes requiring temperatures above 900° C. There are several reasons for the seemingly slow development, chief among which were, the high cost of molybdenum and the very careful operation required to keep air and moisture away from the winding above 400° C., to prevent oxidation.

One of the earliest forms of this type of furnace consisted of an Alundum tube 2.3 cm. inside diameter by 46 cm. long, wound with Molybdenum ribbon .184 mm. thick x 2.54 mm. wide and 445 cm. long. The tube was enclosed in a welded sheet steel casing packed with powdered silica. This furnace was capable of obtaining 1600° C., on 80 volts with 14.3 amperes. It required about 1½ hours to reach this temperature.

Since the improvements in the manufacture of molybdenum wire, resulting in considerably lowering its cost, its use as a resistance element has grown rapidly. The past year has witnessed a more rapid development and a greater industrial use of these furnaces due largely to the introduction of Tungsten-Carbides.

We have been operating one of the tubular furnaces for the manufacture of Carboloy tipped circular saws. Since this furnace was of the laboratory size, being only 3 inches in diameter, it was not adequate for our production requirements and we have recently installed a square or box type furnace which is the latest development by the General Electric Company.

This furnace consists of a heating chamber 36" long by 6" wide by 4" high, having molybdenum wire heating elements mounted on each side and above the chamber, 18" long. These units are wound on alundum tile and are exposed. The hearth tile is of channel cross section to prevent work in the furnace from falling against the winding or the operator striking it with the tongs. A vertical sliding door at the front permits charging the furnace. At the opposite end is a cooling chamber 24" long. Between the heating and cooling chambers, there is an air tight gate valve protected from the high temperature by a tile slide.

Hydrogen is fed into the furnace and cooling chambers from the top, controlled by globe and needle valves, and is discharged through a peep hole in the charging door and a pilot under the discharge door of the cooling chamber.

Energy is supplied at 220 volts, 60-cycle, single phase through a two pole contactor to an autotransformer, having taps from 20 volts up connected to a selector switch and thence to the furnace. The contactor is controlled by a relay. Temperature control at the present time is hand operated, but just as soon as data is available on the steel-alumel thermocouples, it will be made automatic.

Plate I, is a view of this furnace. A unique feature of this furnace is the illuminating gas curtains at the charging door and at the discharge door on the cooling chamber. Without such a seal it would be necessary to increase the flow of hydrogen whenever either door was opened otherwise air would enter. Illuminating gas is used because it is cheaper than hydrogen. The operating lever of the charging door controls a valve which allows illuminating gas to flow into a slotted pipe located below the hearth so that before the door has opened the gas is ignited forming a curtain which completely covers the opening. Upon closing the door, the illuminating gas is shut off and the hydrogen continues to burn as it escapes through the peep

*Products Engineer, Henry L. Disston and Sons., Inc., Philadelphia, Pa.

hole. Just below the discharge door is the hydrogen exhaust from the cooling chamber which should always be burning when the furnace is in operation. Adjacent to this exhause is an illuminating gas pilot which also is kept ignited. The pipes are so arranged that should either be extinguished it would

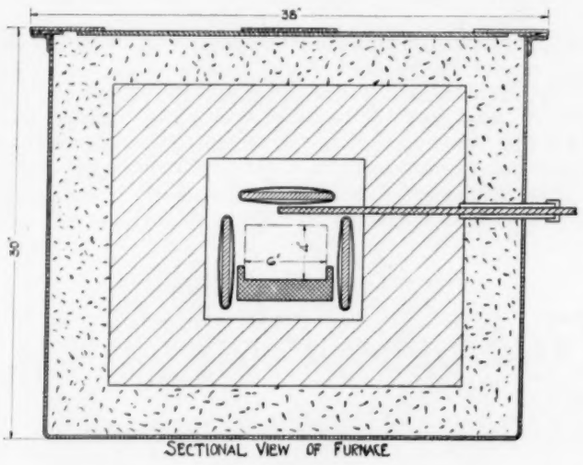


FIG. 1.

instantly be ignited by the other. The operating lever of the discharge door also operates a valve on the illuminating gas line so that the opening of the door opens the valve and the illuminating gas is ignited by the pilot forming a curtain over the opening. Upon closing the door the illuminating gas supply is cut off.

When the furnaces are first put in service they must be thoroughly dried out at low temperature, not exceeding 200° C., for a period of at least 48 hours and then gradually stepped up to about 800° C., and again held for a period of about 24 hours. The furnace may then be brought up to final temperature gradually. This precaution is taken to insure all moisture being driven off otherwise the molybdenum wire would oxidize causing a burn-out. Any hydrogen furnace of this type, after standing for several months, should be dried in this manner before applying heat. The slower the furnace is brought to temperature the first time, the longer will be its life.

In starting a molybdenum wound furnace, the hydrogen, after being passed through sulphuric acid and over sodium hydroxide crystals to purify it and remove any moisture, is admitted to the furnace through the globe and needle valves. Petcocks are provided on each end of the heating chamber at the bottom of the furnace which are opened for testing the furnace atmosphere. All other openings should be closed. A metal test tube is held over the petcocks long enough to replace the air in the tube with furnace gas. The tube still inverted is then removed from the vicinity of the furnace and ignited. If the gas in the test tube does not continue to burn but is blown out by the resulting explosion, it is not safe to start the furnace, but if it continues to burn for a few seconds, it is then safe to start. The petcocks should then be closed and the hydrogen gas ignited at the peep hole in the charging door. The current may now be turned on.

Since the cold resistance of molybdenum wire is approximately 1/6 of that when hot, it is necessary to start a molybdenum wound hydrogen furnace at a comparatively low voltage and gradually increase it as the resistance of the winding is increased by the increased temperature. This is accomplished by the auto-transformer and selector switch.

After the ammeter reading has dropped back to 32 amperes on the 20-volt tap, the switch should be moved to the 50-volt tap. When the ammeter has dropped to 50, it may be moved to the 80-volt tap. When the current drops to 58 amperes, it may be switched to 110 volts and when it has then dropped to 73 amperes, the switch should be moved to the 120-volt tap.

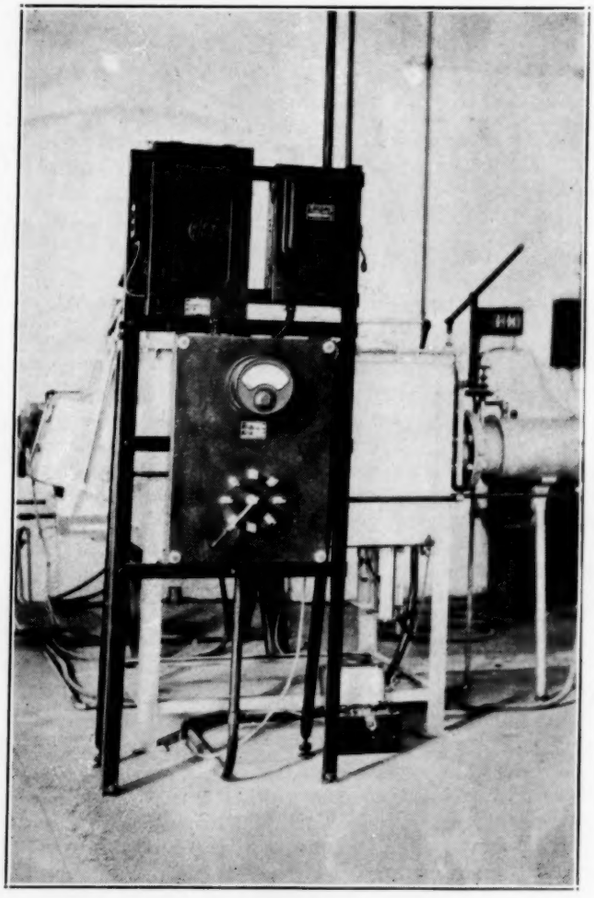


FIG. 2.

Care should be taken when the power is increased to reduce the hydrogen supply so that too much pressure is not built up in the furnace due to the sudden expansion of hydrogen. When power is shut off or the supply fails, the hydrogen flow should be increased temporarily to take care of the hydrogen contraction, otherwise air might be drawn back through the exhaust and cause an explosion.

The cooling chamber is now purged with hydrogen gas and tests made by taking samples as before. The exhaust pipe under the discharge door is then ignited.

The main control valve on the illuminating gas line can now be opened. The pilot will instantly be ignited by the burning hydrogen at the discharge door.

The material to be brazed is put into the furnace on graphite or carbon boats. After the charge has reached the required temperature, the gate valve between the furnace and cooling chamber is opened and the tile slide is lowered permitting the boat to be pushed through into the cooling chamber. The tile slide is then replaced and the gate valve closed. The cooling chamber is kept at low temperature by means of a water jacket and the material is allowed to remain here until it is capable of being handled or until it has reached room temperature.

In working with Carboloy, it is essential that the braze be kept in the hydrogen atmosphere until it has cooled to room temperature other wise oxidation will seriously affect what might appear to be a good copper braze.

Plate II is a cross sectional view of the furnace showing the molybdenum units mounted on alundum tile on each side and top of the chamber. The position of the steel-alumel thermocouple is also shown.

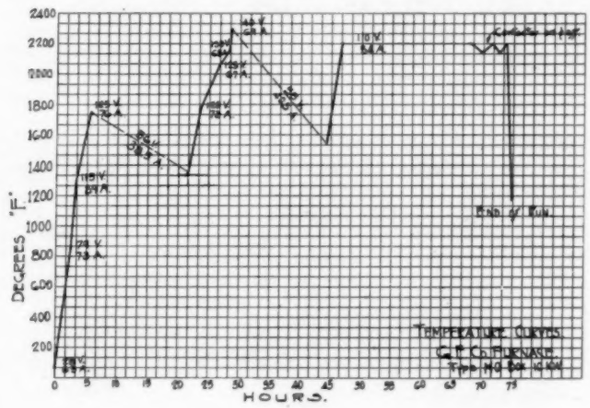


FIG. 3.

Plate III is the temperature curve obtained from a test run on this furnace. It will be seen that it required about 8 hours to bring the furnace from room temperature to 2200° F. After standing for about 17 hours on 55 volts the temperature dropped to about 1350° F. and it then only required 3 to 4 hours to bring it up to 2200° F. When kept on 110 volts for 24 hours the current consumption was 54 amperes which means that the losses at 2200° F. are approximately 5.5 to 6 K.W. at a room temperature of 75° F.

Plate IV shows the heat distribution curves for three temperatures measured every two inches throughout the length of the furnace chamber. It will be noted that the curve at the highest temperature (2200° F.) is fairly flat throughout the 18" length of the heating unit.

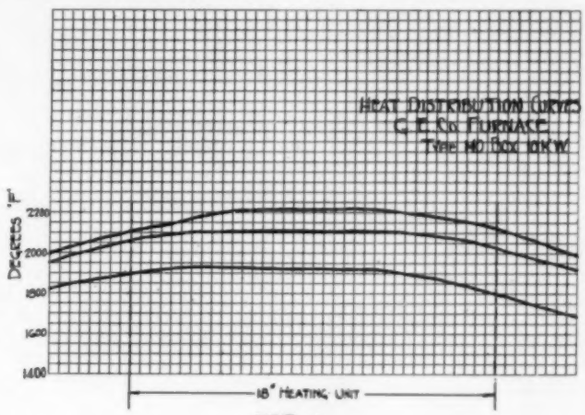


FIG. 4.

The hydrogen consumption of this furnace is about 10 to 12 cu. ft. per hour with door closed and the furnace is guaranteed to handle 25 pounds of material per hour. On the first run, we actually brazed 30 pounds and consumed 200 cu. ft. of hydrogen, during a period of 8.5 hours, or a consumption of 23.5 cu. ft. of hydrogen per hour.

I am not prepared to give any definite figures on the life of the windings of these furnaces, although we have been operating one of the 3" round muffle type furnaces intermittently for nine months.

Molybdenum wire .08" in diameter was placed in three locations in the furnace, at a temperature of 1200° C. and the door opened and closed 12 times allowing air to flow back over the hearth. The average reduction in diameter was .006". After being subjected to the same temperature for six hours, the wire was bent double on 1/8" radius without breaking. The return bend broke the wire. This test clearly indicates the improvements accomplished in the manufacture of molybdenum wire for heating elements.

No definite figures are available on the cost of operating a molybdenum wound furnace of this type because this is the first one installed on production work and has only been operating one week. Cheaper methods of producing hydrogen are already being developed which will materially reduce the operating cost of these furnaces.

In closing, I wish to take this opportunity to thank Mr. P. H. Clark of the Industrial Heating Department of the General Electric Company, at Schenectady, for some of the test figures presented.

ASSOCIATION OF IRON & STEEL ELECTRICAL ENGINEERS
CONVENTION AND IRON AND STEEL EXPOSITION
JUNE 15-16-17-18-19, 1931
ELECTRICAL, MECHANICAL, LUBRICATING, COMBUSTION, SAFETY
ENGINEERING DIVISIONS, AND WIRE & WIRE PRODUCTS
EXPOSITION—CLEVELAND AUDITORIUM
ALL TECHNICAL SESSIONS—CLEVELAND AUDITORIUM
ALL SOCIAL FUNCTIONS—CLEVELAND AUDITORIUM
ALL ACTIVITIES UNDER ONE ROOF

(Continued from Page V)

Ward Harrison, Dir. of Illumination, National Lamp Works, Cleveland, Ohio.
F. A. Tremallen, Foreman, Pwr. House Lines, Bethlehem Steel Co., Johnstown, Pa.
J. R. Ibach, Elec. Supt., Aluminum Co. of America, Massena, N. Y.

WELDING COMMITTEE

Chairman, S. S. Wales, Chief Elec. Engr., Carnegie Steel Co., Pittsburgh, Pa.
A. W. Steed, Supt. of Maint., American Rolling Mills Company, Middletown, Ohio.
R. M. Hussey, Supt. Rod & Wire Mills, Jones & Laughlin Steel Corp., Aliquippa, Pa.
A. J. Standing, Elec. Supt., Saucon Plant, Bethlehem Steel Co., Bethlehem, Pa.
J. H. McElhinney, Gen. Supt., Lukens Steel Co., Coatesville, Pa.
Elbert Lewis, Asst. Elec. Engr., Illinois Steel Co., South Chicago, Ill.
J. C. Reed, Elec. Supt., Bethlehem Steel Co., Steelton, Pa.
C. B. Seagle, Elec. Engr., American Bridge Co., Ambridge, Pa.
W. W. Garrett, Elec. Engr., Tennessee Coal Iron & R. R. Co., Ensley, Ala.
G. A. Hughes, Elec. Engr., Truscon Steel Co., Youngstown, Ohio.
E. L. Upp, Elec. Supt., National Tube Co., McKeesport, Pa.
E. Tyler Davis, V. P., Tyler Tube & Pipe Co., Washington, Pa.
J. S. O'Donovan, Elec. Supt., Spang Chalfant Co., Etna, Pa.
E. A. Aik, A. O. Smith Corp., Milwaukee, Wis.
Charles Schenk, Supt. of Production, Bethlehem Steel Co., Bethlehem, Pa.
C. M. Myers, Asst. Elec. Engr., Youngstown Sheet & Tube Co., Youngstown, Ohio.
F. W. Cramer, Chief Elec. Engr., Republic Steel Corp., Youngstown, Ohio.
A. A. Stewart, Elec. Supt., Pittsburgh Steel Company, Monessen, Pa.

ELECTRIC HEAT COMMITTEE

Chairman, C. S. Proudfoot, Genl. Mgr., Vanadium Corp. of America, Niagara Falls, N. Y.
Wirt Scott, Westinghouse Elec. & Mfg. Co., Mansfield, Ohio.
R. H. Bryant, Elec. Engr., American Steel & Wire Co., Worcester, Mass.
R. W. Heller, Power Engr., Duquesne Light Co., Pittsburgh, Pa.
J. W. Bates, American Sheet & Tin Plate Co., Pittsburgh, Pa.
R. M. Cherry, Engr., General Electric Co., Schenectady, N. Y.
W. W. Wallis, President, Pittsburgh Electric Furnace Co., Pittsburgh, Pa.
Geo. H. Schaeffer, Elec. Engr., Carpenter Steel Co., Reading, Pa.
R. J. Hartley, Engr., Simmons Saw & Steel Co., Lockport, N. Y.
E. N. Calhoun, Sales Mgr., Edwin L. Wiegand Co., Pittsburgh, Pa.
C. F. Cone, Engr., Geo. J. Hagan Co., Pittsburgh, Pa.
D. M. Petty, Supt. of Service Depts. Bethlehem Steel Co., Bethlehem, Pa.
F. C. Watson, Elec. Engr., International Nickel Co., Huntington, W. Va.
J. D. Donovan, Elec. & Mech. Supt., Republic Steel Corp., Massillon, Ohio.
R. F. Benzinger, Vice Pres., Electric Furnace Co., Salem, Ohio.
E. F. Northrup, Vice Pres., Ajax Electro Thermic Corp., Philadelphia, Pa.
S. Arnold, III, Sales Engr., Heroult Electric Furnaces, Pittsburgh, Pa.
W. G. Jahn, Engr., American Sheet & Tin Plate Co., Gary, Ind.
A. W. Duncan, Elec. Supt., Weirton Steel Co., Weirton, W. Va.
C. H. Fielding, Works Supt., Rustless Iron Corp., Baltimore, Md.
O. M. Svensson, Engr., Vanadium Corp. of America, Bridgeville, Pa.

ELECTRICAL DEVELOPMENTS COMMITTEE

Chairman, W. H. Burr, Elec. Supt., Lukens Steel Co., Coatesville, Pa.

Main Roll Division

W. B. Shirk, Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.
J. D. Wright, General Electric Co., Schenectady, N. Y.
R. W. Davis, Allis Chalmers Mfg. Co., Milwaukee, Wis.
W. H. Feldman, Electric Machinery Mfg. Co., Minneapolis, Minn.
A. C. Bunker, Crocker Wheeler Elec. Mfg. Co., Ampere, N. J.

Auxiliary Drives and General Purpose Motors Division

A. M. McCutcheon, Reliance Elec. & Engr. Co., Cleveland, Ohio.
J. R. Lewis, Crocker Wheeler Elec. Mfg. Co., Pittsburgh, Pa.
J. C. Barry, General Electric Co., Erie, Pa.
W. H. Powell, Allis Chalmers Mfg. Co., Milwaukee, Wis.
J. S. Lincoln, Lincoln Electric Co., Cleveland, Ohio.
H. S. Stockdale, Electro Dynamic Co., Pittsburgh, Pa.
L. H. Tippins, U. S. Electrical Mfg. Co., Pittsburgh, Pa.

Control Division

N. L. Mortensen, Cutler Hammer Inc., Milwaukee, Wis.
W. H. Williams, Clark Controller Co., Cleveland, Ohio.
R. G. Widdows, Electric Con. & Mfg. Co., Cleveland, O.
L. A. Umansky, General Electric Co., Schenectady, N. Y.
D. W. Deans, Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa.
Jos. F. Frese, Monitor Controller Co., Baltimore, Md.
J. S. Rowan, Rowan Controller Co., Baltimore, Md.

Crane Division

G. W. Yanney, Alliance Machine Co., Alliance, Ohio.
F. H. Barnard, Morgan Engineering Co., Alliance, Ohio.
E. C. Gainsborg, Cleveland Crane & Engr. Co., Pittsburgh, Pa.
Earl Raysor, Manning Maxwell & Moore, Inc., Youngstown, Ohio.
Sidney Buckley, Shepard Niles Crane & Hoist Corp., Philadelphia, Pa.
Norman Farrar, Harnischfeger Corp., Milwaukee, Wis.
H. P. O'Neil, Milwaukee Elec. Crane & Hoist Co., Milwaukee, Wis.

Transmission Equipment Division

F. E. Fairman, General Electric Company, Pittsburgh, Pa.
M. J. Wohlgemuth, Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa.
Samuel Horelick, Pennsylvania Transformer Co., Pittsburgh, Pa.
G. L. Crosby, Roller Smith Co., New York, N. Y.
P. C. Gunion, ITE Circuit Breaker Co., Philadelphia, Pa.
R. F. Gooding, Condit Elec. Mfg. Corp., Pittsburgh, Pa.

A. F. Alsaker, Delta Star Electric Co., Chicago, Ill.
R. E. Zimmerman, Railway & Ind. Engr. Co., Greensburg, Pa.
L. R. Lewis, Electric Power Equipment Corp., Philadelphia, Pa.
J. J. Mullen, Moloney Electric Co., St. Louis, Mo.
J. S. Livingston, Schweitzer & Conrad, Chicago, Ill.
L. B. Gawthrop, Electric Service Supplies Co., Philadelphia, Pa.
Grover W. Lapp, Lapp Insulator Co., LeRoy, N. Y.
W. W. Lewis, General Electric Co., Schenectady, N. Y.
K. A. Hawley, Locke Insulator Co., Baltimore, Md.
D. C. Hopper, Duquesne Light Co., Pittsburgh, Pa.
R. L. Baker, Metropolitan Edison Co., Reading, Pa.
M. E. Noyes, Aluminum Co. of America, Pittsburgh, Pa.
H. E. Ransford, G & W Electric Specialties Co., Pittsburgh, Pa.
C. H. Kenney, General Cable Corporation, New York, N. Y.
J. J. O'Brien, Okonite Company, Chicago, Ill.
J. S. Rashba, Rockbestos Products Corp., Pittsburgh, Pa.
A. N. Cartwright, West Penn Power Co., Pittsburgh, Pa.
R. F. Mason, International Nickel Corp., New York, N. Y.
Max Rubenstein, Cable Accessories Corp., Pittsburgh, Pa.

Generating Equipment Division

R. H. Wright, Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.
Saul Lavine, General Electric Co., Pittsburgh, Pa.
W. H. Powell, Allis Chalmers Mfg. Co., Milwaukee, Wis.

Miscellaneous Division

C. L. Snyder, Appleton Electric Co., Pittsburgh, Pa.
J. J. Bangert, Crouse Hinds Co., Pittsburgh, Pa.
M. S. Robinson, Erie Malleable Iron Co., Pittsburgh, Pa.
A. E. Tregenza, Jefferson Electric Co., Chicago, Ill.
T. P. McGinnis, Pyle National Co., Pittsburgh, Pa.
C. C. Lafferty, National Electric Products Co., Chicago, Ill.
W. D. Hodson, Hodson Corporation, Chicago, Ill.
C. O. Norstrum, Keystone Lubricating Co., Philadelphia, Pa.
Geo. P. Dempler, Geo. P. Dempler Co., Pittsburgh, Pa.

Instruments

R. M. Walker, Bristol Company, Pittsburgh, Pa.
A. R. Richardson, General Electric Co., Philadelphia, Pa.
G. L. Crosby, Roller Smith Co., New York, N. Y.
W. B. Shirk, Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.
L. D. Joralemon, Weston Electrical Instrument Co., Philadelphia, Pa.
H. F. Darby, Jr., Jewell Electrical Instrument Co., Philadelphia, Pa.
L. O. Morrow, Esterline-Angus Co., Philadelphia, Pa.
G. D. Conlee, Republic Flow Meters Co., Chicago, Ill.
G. L. Clapper, Brown Instrument Co., Pittsburgh, Pa.
I. M. Stein, Leeds & Northrup Co., Philadelphia, Pa.

PORTABLE ELECTRICAL TOOL COMMITTEE

Chairman, A. L. Reichert, Elec. Supt., Bourne Fuller Co., Cleveland, Ohio.
W. C. Buske, Master Mech., McConway & Torley Co., Pittsburgh, Pa
A. F. Jones, Chief Elec., Champion Machine & Forging Co., Cleveland, Ohio.
F. M. Sturgess, Chief Elect., American Steel & Wire Co., Fairfield, Ala.
W. C. McClelland, Elec. Supt., Standard Tin Plate Co., Canonsburg, Pa.
George H. McFeaters, Elec. Engr., Lorain Steel Co., Johnstown, Pa.
S. E. McQuigg, Chief Elect., Allegheny Steel Co., Brackenridge, Pa.
P. J. McGrane, Chief Elec., Railway Steel Spring Co., Chicago Heights, Ill.
James Maloney, Chief Elect., Superior Steel Co., Carnegie, Pa.
Henry Molz, Chief Elec., Allegheny River Mining Co., Kittanning, Pa.
J. R. Penman, Elec. Supt., Reading Iron Co., Reading, Pa.
C. J. Garrigan, Elec. Engr., Pittsburgh Rolls Corp., Pittsburgh, Pa.
J. S. O'Donovan, Elec. Supt., Spang Chalfant Co., Etna, Pa.
W. J. Davis, Chief Elect., Scullin Steel Co., St. Louis, Mo.
H. F. Raab, Asst. Elec. Supt., Bethlehem Steel Co., Johnstown, Pa.
D. W. McFadyen, Chief Elect., Universal Portland Cement Co., Universal, Pa.
William Anderson, Chief Elect., Sellers Mfg. Co., Chicago, Ill.
W. P. Stark, Chief Elec. Engr., Apollo Steel Co., Apollo, Pa.
James Riles, Elec. Supt., A. M. Byers Co., Pittsburgh, Pa.
I. J. McAnlis, Chief Elec., Standard Steel Car Co., New Castle, Pa.
J. R. Lytle, Chief Elect., Vulcan Mould & Iron Co., Latrobe, Pa.
James H. Reiners, Elec. Engr., Pittsburgh Screw & Bolt Co., N. S., Pittsburgh, Pa.
George Pfeffer, Chief Elect., Florence Pipe Foundry & Machine Co., Florence, N. J.
J. C. Ritchey, Elec. Engr., Pressed Steel Car Co., McKees Rocks, Pa.
J. D. Scully, Elec. Engr., National Tube Co., McKeesport, Pa.
R. F. Waldo, Dist. Mgr., Ideal Commutator Dresser Co., Pittsburgh, Pa.
H. McFarland, Sales Mgr., Martindale Electric Co., Cleveland, Ohio.

AIR CONDITIONING COMMITTEE

Chairman, T. J. Flaherty, Elec. Supt., American Rolling Mills Co., Ashland, Ky.
R. E. Lewis, Elec. Supt., Youngstown Sheet & Tube Co., Youngstown, Ohio.
J. H. Milliken, American Air Filter, Inc., Chicago, Ill.
T. E. Hughes, Genl. Foreman, Carnegie Steel Co., Duquesne, Pa.
W. B. Rese, Elec. Engr., Great Lakes Steel Co., Ecourse, Mich.
W. H. Beyerly, Asst. Elec. Supt., Bethlehem Steel Co., Sparrows Point, Md.
G. Rees Carroll, Elec. Supt., Jones & Laughlin Steel Corp., Aliquippa, Pa.
W. S. Hall, Supt. Engr. & Const., Illinois Steel Co., South Chicago, Ill.
J. E. Sayer, Asst. Chief Elec., Tennessee Coal Iron & R. R. Co., Ensley, Ala.

TRANSPORTATION COMMITTEE

J. W. Bates, American Sheet & Tin Plate Co., Pittsburgh, Pa.
Frank Mohr, Warren Plant, Republic Steel Corp., Warren, Ohio.
C. W. Chappelle, Geo. D. Whitcomb Co., Pittsburgh, Pa.
Geo. H. Criss, H. E. McCoy Co., Pittsburgh, Pa.

A. H. Candee, Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.
R. S. Richards, Atlas Car Mfg. Co., Cleveland, Ohio.
C. H. Moehler, Yale & Towne Mfg. Co., Pittsburgh, Pa.
R. F. Hibbard, Wright Hibbard Electric Truck Corp., Phelps, N. Y.
L. N. Crissman, Electric Storage Battery Co., Pittsburgh, Pa.
J. K. Mahaffey, Edison Storage Battery Co., Pittsburgh, Pa.
G. M. Barker, Philadelphia Storage Battery Co., Pittsburgh, Pa.
E. Coates, Elec. Supt., Republic Steel Corp., Buffalo, N. Y.

SHOP PRACTICES COMMITTEE

Chairman, J. J. Booth, Elec. Supt., National Tube Co., Gary, Ind.
O. H. Meineke, Elec. Supt., Spang Chalfant Co., Ambridge, Pa.
W. P. Stark, Elec. Supt., Apollo Steel Co., Apollo, Pa.
Geo. Pfeffer, Elec. Supt., Florence Pipe Foundry & Machine Co., Florence, N. J.
C. M. Thompson, Jr., Prod. Engr., Henry Disston Sons, Inc., Tacony, Philadelphia, Pa.
Chas. Giles, Elec. Dept., National Tube Co., McKeesport, Pa.
R. F. Gale, Plant Engr., Midvale Company, Nicetown, Pa.
W. W. Barefoot, Elec. Supt., Carnegie Steel Co., McKees Rocks, Pa.
C. E. Miller, Elec. Supt., Carnegie Steel Co., Clairton, Pa.
J. S. Murray, Chief Elec. Engr., Follansbee Bros. Co., Toronto, Ohio.
Paul Canney, Elec. Supt., Minnesota Steel Co., Duluth, Minn.
W. B. Connally, Elec. Supt., Gulf States Steel Co., Alabama City, Ala.

COMBUSTION ENGINEERING DIVISION

EXECUTIVE COMMITTEE

Engineering Section Director, Chairman, Walter N. Flanagan, Special Engr., Carnegie Steel Co., Pittsburgh, Pa.
Secretary, T. J. Ess, Comb. Engr., Republic Steel Corp., Massillon, Ohio.
H. V. Flagg, Asst. Comb. Engr., American Rolling Mills Co., Middletown, Ohio.
Martin J. Conway, Comb. Engr., Lukens Steel Co., Coatesville, Pa.

Gas Utilization Section

Chairman, F. M. Washburn, Met., Wisconsin Steel Co., South Chicago, Ill.
Walter N. Flanagan, Special Engr., Carnegie Steel Co., Pittsburgh, Pa.
A. G. Witting, Chief Engr., Illinois Steel Co., Gary, Ind.
F. G. Cutler, Chief Bureau of Steam Engr., Tennessee Coal Iron & R. R. Co., Ensley, Ala.
J. G. West, Genl. Supt., N. S. Works, Jones & Laughlin Steel Corp., Pittsburgh, Pa.
A. J. Boynton, Engr., H. A. Brassert & Co., Chicago, Ill.
W. H. Cosgrove, Pres., Gas Combustion Co., Pittsburgh, Pa.
W. E. Bisler, Engr., Combustion Engr. Corp., New York, N. Y.
J. C. Hayes, Engr., Freyn Engineering Co., Chicago, Ill.
Karl L. Landgrebe, Vice Pres., Tennessee Coal Iron & R. R. Co., Birmingham, Ala.
J. W. Jones, Steam Engr., Wheeling Steel Corp., Portsmouth, Ohio.
Wilfred Sykes, Vice Pres., Inland Steel Co., Indiana Harbor, Ind.
W. J. McGurty, Bartlett Hayward Co., Baltimore, Md.
C. W. Hedberg, Research Corp., Bound Brook, N. J.
J. L. Hott, Comb. Engr., Wickwire Spencer Steel Co., Buffalo, N. Y.

Gas Producer Section

Chairman, E. A Hawk, Steam Engr. Dept., Tennessee Coal Iron & R. R. Co., Ensley, Ala.
G. R. McDermott, Vice Pres., Chapman Stein Furnace Co., Mt. Vernon, Ohio.
A. L. Foell, Chief Engr., Arthur G. McKee Co., Cleveland, Ohio.
Walter de Fries, Chief Engr., Wm. B. Pollock Co., Youngstown, Ohio.
L. C. Edgar, Chief Engr., Carnegie Steel Co., Braddock, Pa.
W. J. Harper, Chief Engr., Republic Steel Corp., Buffalo, N. Y.
H. C. Seibert, Comb. Engr., Bethlehem Steel Co., Bethlehem, Pa.
J. W. Jones, Steam Engr., Wheeling Steel Corp., Portsmouth, Ohio.
S. M. Jenks, Fuel Engr., American Sheet & Tin Plate Co., Gary, Ind.

Steam Generation and Utilization Section

Chairman, J. D. Donovan, Elec. & Mech. Supt., Republic Steel Corp., Massillon, Ohio.
L. C. Edgar, Chief Engr., Carnegie Steel Co., Braddock, Pa.
E. W. Trexler, Supt. of Mech Dept., Bethlehem Steel Co., Johnstown, Pa.
J. B. Crane, Engr., Combustion Engr. Corp., Pittsburgh, Pa.
James Rath, Power Dept., National Tube Co., McKeesport, Pa.
E. Kieft, Engr. of Tests, Illinois Steel Co., Gary, Ind.
C. H. Verwohlt, Works Engr., Wheeling Steel Corp., Wheeling, W. Va.
A. L. Penniman, Jr., Supt. Steam Sta., Consolidated Gas Electric Light & Power Co., Baltimore, Md.
E. C. McDonald, Asst. Steam Engr., Republic Steel Corp., Buffalo, N. Y.
C. H. Williams, Steam Engr. Dept., Carnegie Steel Co., Ohio Works, Youngstown, Ohio.
E. P. Winters, Power Engr., Sloss Sheffield Steel & Iron Co., North Birmingham, Ala.

Liquid Fuel Section

Chairman, W. J. Harper, Chief Engr., Republic Steel Corp., Buffalo, N. Y.
H. C. Dobrin, Consult. Comb. Engr., Pittsburgh, Pa.
Prof. W. Trinks, Carnegie Institute of Technology, Pittsburgh, Pa.
Fred Clements, Engr., Park Gate Works, Rotherham, England.
H. C. Seibert, Comb. Engr., Bethlehem Steel Co., Bethlehem, Pa.
J. H. McElhinney, Gen. Supt., Lukens Steel Co., Coatesville, Pa.

Furnace Section

Chairman, H. V. Flagg, Comb. Engr., American Rolling Mill Co., Middletown, Ohio.
F. G. Gasche, Comb. Engr., Bethlehem Steel Co., Lackawanna, N. Y.
H. C. Seibert, Comb. Engr., Bethlehem Steel Company, Bethlehem, Pa.
S. Kneass, Chief Engr., A. M. Byers Co., Pittsburgh, Pa.

A. W. Steed, Supt., Maint., American Rolling Mills Co., Middletown, Ohio.
Karl H. Marsh, Chief Engr., British Empire Steel Co., Sydney, N. S., Canada.
G. T. Hollett, Steam Engr., Illinois Steel Co., South Chicago, Ill.
L. Ellman, Vice Pres., M. H. Detrick Co., Pittsburgh, Pa.
Joseph Kennedy, Julian Kennedy Co., Pittsburgh, Pa.
A. L. Culbertson, Dist. Mgr., Rust Engineering Co., Pittsburgh, Pa.
W. R. Culbertson, Sales Engr., Chapman Stein Co., Mt. Vernon, Ohio.
E. H. Younglove, Johns Manville, Inc., Chicago, Ill.
A. G. Witting, Chief Engr., Illinois Steel Co., Gary, Ind.
John Lehnert, Comb. Engr., Republic Steel Corp., Massillon, Ohio.
C. H. Hunt, Vice Pres., National Steel Corp., Weirton, West Va.
S. Naismith, Refractory Engr., Illinois Steel Co., South Chicago, Ill.
W. P. Chandler, Special Engr., Blaw Knox Co., Blaw Knox, Pa.

Instrument and Control Section

Chairman, M. J. Conway, Comb. Engr., Lukens Steel Co., Coatesville, Pa.
J. W. Jones, Steam Engr., Wheeling Steel Corp., Portsmouth, Ohio.
J. G. Allen, Chief Engr., Carnegie Steel Co., New Castle, Pa.
W. P. Chandler, Special Engr., Blaw Knox Co., Blawnox, Pa.
Carl Fischer, Supt. Light, Heat & Power, Mesta Machine Co., West Homestead, Pa.
G. R. McDermott, Vice Pres., Chapman Stein Co., Mt. Vernon, Ohio.
R. M. Walker, Dist. Mgr., Bristol Co., Pittsburgh, Pa.
G. D. Conlee, Chief Engr., Republic Flow Meters Co., Chicago, Ill.
H. R. Maxon, Pres., Maxon Premier Burner Co., Muncie, Ind.
J. M. Hopwood, Pres., Hagan Corporation, Pittsburgh, Pa.
C. H. Smoot, Pres., Smoot Engineering Co., New York, N. Y.

SAFETY ENGINEERING DIVISION

EXECUTIVE COMMITTEE

Chairman, J. A. Voss, Safety Dir., Republic Steel Corp., Youngstown, Ohio.
C. E. Sankey, Ch. Safety Director, National Tube Co., Pittsburgh, Pa.
C. L. Baker, Management's Repr., Bethlehem Steel Co., Lackawanna, N. Y.
R. G. Adair, Supt. of Safety, American Rolling Mills Co., Middletown, Ohio.
Earl Blank, Dir. of Safety, Jones & Laughlin Steel Corp., Pittsburgh, Pa.
A. C. Germain, Safety Dir., Minnesota Steel Co., Duluth, Minn.
H. G. Hensel, Safety Engr., Youngstown Sheet & Tube Co., Indiana Harbor.
F. H. Rowe, Safety Engr., Wheeling Steel Corp., Portsmouth, Ohio.
P. F. Haberstick, Safety Engr., Wheeling Steel Corp., Benwood, W. Va.
J. A. Oartel, Safety Dir., Carnegie Steel Co., Pittsburgh, Pa.
J. A. Northwood, Safety Dir., Bethlehem Steel Co., Sparrows Point, Md.
P. G. Fenlon, Safety Dir., Carnegie Steel Co., Duquesne, Pa.
J. F. Hunter, Safety Engr., Carnegie Steel Co., Pittsburgh, Pa.
F. H. Kittredge, Elec. Supt., Illinois Steel Co., Joliet, Ill.
Stanley Grand Girard, Elec. Engr., Sharon Steel Hoop Co., Sharon, Pa.
G. A. Lamberton, Gen. Foreman, National Tube Co., Lorain, Ohio.
H. W. Darr, Supt. Safety Dept., Bethlehem Steel Co., Johnstown, Pa.

LUBRICATION ENGINEERING DIVISION

EXECUTIVE COMMITTEE

Chairman, C. C. Pecu, Lub. Engr., Bethlehem Steel Co., Lackawanna, N. Y.
Secretary, T. B. Little, Association of Iron & Steel Electrical Engineers, Pittsburgh, Pa.
A. D. Adams, Asst. Gen. Supt., Spang Chalfant Co., Inc., Ambridge, Pa.
D. B. Geeseman, Gen. Mgr., Standard Tin Plate Co., Canonsburg, Pa.
J. A. Clauss, Chief Engr., Great Lakes Steel Company, Ecourse, Mich.
Vic Chartner, Chief Engr., Pittsburgh Steel Co., Monessen, Pa.
C. E. Bedell, Chief Engr., Wheeling Steel Corp., Benwood, W. Va.
J. J. Booth, Elec. Supt., National Tube Co., Gary, Ind.
J. D. Donovan, Elect. & Mech. Supt., Republic Steel Corp., Massillon, Ohio.
N. C. Bye, Chief Engr., Henry L. Disston's & Sons, Inc., Tacony, Philadelphia, Pa.
C. A. Bollinger, M. M., American Sheet & Tin Plate Co., New Castle, Pa.
F. J. Binckes, Asst. Chief Engr., Inland Steel Co., Indiana Harbor, Ind.
C. A. Baumann, Chief Mech. Engr., Carnegie Steel Co., Clairton, Pa.
J. C. Green, Asst. Engr., Pittsburgh Crucible Steel Co., Midland, Pa.
H. G. Gibson, M. M., McKeesport Tin Plate Co., McKeesport, Pa.
C. J. Duby, Asst. Chief Engr., Republic Steel Corp., Warren, Ohio.
Gordon Gage, Supt. Maintenance, American Rolling Mill Co., Butler, Pa.
Carl S. Walrab, M. M., Calumet Steel Co., Chicago Heights, Ill.
L. A. Wynd, M. M., Keystone Steel & Wire Co., Peoria, Ill.
J. M. Faris, Asst. to Vice Pres., Youngstown Sheet & Tube Co., Youngstown, Ohio.
E. C. Kirkpatrick, Mech. Engr., Steel Company of Canada, Montreal, Quebec, Canada.
L. F. Coffin, Gen. Master Mechanic, Bethlehem Steel Co., Sparrows Point, Md.
S. N. Roberts, Mech. & Elec. Supt., Atlantic Steel Co., Atlanta, Ga.
R. C. Mohler, Dist. Engr., American Steel & Wire Co., Pittsburgh, Pa.
Howard M. Miner, M. M., Follansbee Bros., Toronto, O.
H. F. Martin, Asst. M. M., Jones & Laughlin Steel Corp., Aliquippa, Pa.
B. S. Burrell, Master Mech., Inland Steel Co., Indiana Harbor, Ind.
John F. Pelly, Bethlehem Steel Co., Bethlehem, Pa.
Samuel Roberts, Lubr. Engr., Carnegie Steel Co., Homestead, Pa.
John M. Husher, Gen. Master Mech., Pittsburgh Steel Co., Monessen, Pa.

Items of Interest

GEORGE W. RICHARDSON

Mr. George W. Richardson a charter member of the Association of Iron and Steel Electrical Engineers died August 22nd, 1930. Mr. Richardson retired from active business in 1925 and made his home in Atlantic City, N. J. He began his career at the Easton Pennsylvania Car Shops, later going with the Harrison Sugar Refining Company at Philadelphia.

In 1886 he located with the American Bridge Company at Pencoyd, Pa., and remained with them for thirty-eight years, being the Electrical Superintendent for twenty-five years. Mr. Richardson was an active steel mill executive and contributed many ingenious electrical devices to that industry. His educational contributions to the Association of Iron and Steel Electrical Engineers were many and the proceedings and transactions of that society contains many papers and opinions which helped to develop the application of electricity to the Iron and Steel Industry.

Mr. Richardson enjoyed a wide acquaintanceship in the Steel Industry who all will be sorry to learn of his death. The Association of Iron and Steel Electrical Engineers through the Iron and Steel Engineer offers their condolence and sympathy to his family.

L. M. Ripple has resigned his position as Electric Engineer at the Central Alloy Division of the Republic Steel Corporation to accept a position as Electric Superintendent at the Great Lakes Steel Corporation, Detroit, Michigan.

John W. Close, Sr., who was connected with M. A. Hanna Company died June 2nd. Burial at Ashtabula, Ohio where he resides for the past twenty-two years. Mr. Close was a well known figure throughout the Steel Industry.

A. H. Lauer has been made Works Engineer of the American Steel Foundries, Granite City, Illinois. His former position was special engineer. He succeeded Mr. L. C. Lucas who resigned.

C. C. PECU

Mr. C. C. Pecu, Chairman, Lubrication Engineering Division of the Association of Iron and Steel Electrical Engineers. Mr. Pecu is the Lubrication Engineer of the Lackawanna plant of the Bethlehem Steel Company, Lackawanna, New York.

Mr. E. M. Richards, formerly Chief Industrial Engineer, Jones and Laughlin Steel Corporation has resigned to accept a position with the Republic Steel Corporation at Youngstown, Ohio.

Mr. C. A. Bollinger formerly Master Mechanic of the Chester Works of the American Sheet and Tin Plate Company has been transferred to the New Castle Works of the same company as Master Mechanic, succeeding P. W. Carey, deceased. H. F. Tustin formerly Fuel Engineer at the New Castle Works has succeeded Mr. Bollinger.

James A. Farrington, Electrical Superintendent of the Wheeling Steel Corporation at Steubenville, Ohio and one of the founders of the A. I. & S. E. E., recently resigned his office as Treasurer of the Association. The Board of Directors with regret accepted Mr. Farrington's resignation as Treasurer but in recognition of his tremendous service and untiring efforts for the Association the Board unanimously conferred upon him the title of Honorary and Life Director and Mr. Farrington will act in an advisory capacity to the officers of the Association.

J. H. Van Campen has been appointed Chief Engineer of the Republic Steel Corporation with offices at Youngstown, Ohio. Mr. Van Campen succeeds Mr. S. H. McKee who resigned recently. Mr. Van Campen was formerly Chief Engineer of the Warren Works of the Republic Steel Corporation. He is an active member of the Association of Iron and Steel Electrical Engineers and is serving on the Developments in Rolling Mill Practices Committee also on the Special Committee on Bearings. The Association membership are extending their best wishes for his success in his new position.